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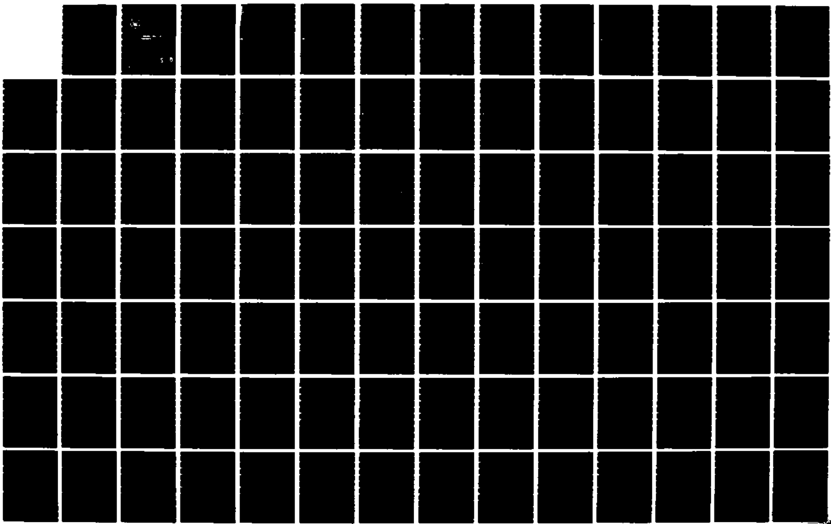

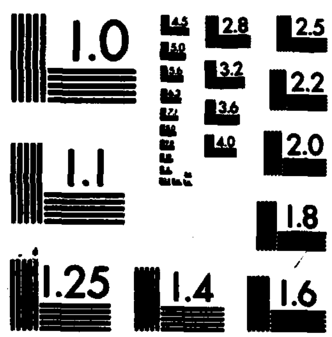

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ECONOMIC ANALYSIS HANDBOOK

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
200 STOVALL STREET
ALEXANDRIA, VA. 22332

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FOREWORD

Increasing fiscal pressures today make the job of the resource manager more crucial than ever before. The words "do more with less" constitute more than merely a catchy phrase; they are a succinct statement of fiscal reality. Decision-makers at all levels of authority are being called upon to justify their resource allocation decisions as cost effective. While at first glance this constraint may seem unnecessarily burdensome, upon reflection the prudent individual will recognize that it is both proper and essential to effective resource management. Progress attained through informed choice is greater than that attained by chance or by hunch decisions. Consistent with this philosophy, Congress and the Department of Defense place strong emphasis on sound economic justification for Navy investments.

The Naval Facilities Engineering Command (NAVFAC) answered this requirement beginning in 1970 with its economic analysis program which has included conducting economic analysis seminars for all Navy Commands, Claimants, and Activity personnel; participating in the deliberations of the Defense Economic Analysis Council (DEAC); and, in conjunction with the Civil Engineer Corps Officers School, developing a one week Economic Analysis Course for middle management and working level personnel of the Naval Shore Establishment. Basic to all of these efforts, however, was the need for an Economic Analysis Handbook. The first edition of NAVFAC P-442 was developed and distributed for Navy wide use in May 1971.

With changing times, the first handbook became technically out of date and was revised by NAVFAC P-442 of June 1975, which provided additional guidance on how to handle inflation and other cost escalations in economic analyses as well as emphasis on sensitivity analysis to ensure that analytical findings are well formulated.

This edition of the handbook provides revised guidance on the treatment of inflation in economic analysis, increased emphasis on the use of sensitivity analysis, additional guidance on the treatment of risk, and updates specific guidance for Navy programs, especially those related to energy conservation. ~~Additional appendices~~ have also been — Go to 1. included so that the handbook may serve as a reference for even the most experienced analyst. NAVFAC P-442 of June 1975 is hereby cancelled and superseded.

This handbook is compiled by the Assistant Commander for Facilities Planning and Real Estate of the Naval Facilities Engineering Command. As updated versions of the document will be published periodically, comments and suggestions on its content and format are invited and should be directed to the Commander, Naval Facilities Engineering Command (Attn: The Systems Analysis Division, Code 203), Alexandria, VA 22332.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

This publication is certified as an official Command publication and has been reviewed and approved in accordance with Secretary of the Navy Instruction 5600.16.

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I. INTRODUCTION

A. PERSPECTIVE

Today's decision-maker requires quantitative information and analyses, to assure the most effective use of scarce resources. Today's decisions also involve complex issues frequently requiring high investment and operations costs with varying uncertainties. Therefore, the decision-maker needs a comprehensive economic analysis today for tomorrow's decision.

The material developed in this Economic Analysis Handbook is premised on the concept of a few basic economic and commonsense principles. This handbook is a "how to do it" treatise of the techniques required to prepare an economic analysis. The approach of the handbook is to assume that the reader is a novice in the field of economic analysis (benefit/cost analysis), so the material is developed slowly from simple examples and principles.

Although the methods of analysis considered herein are applicable to a wide variety of engineering and economic decisions, this handbook is oriented toward facility applications. Since this handbook is intended to be a practical rather than theoretical guide, examples are kept as simple as possible to illustrate application of the subject matter. Some readers may find this handbook too slowly paced. To such readers, the authors extend their apologies and suggest skipping over easy and familiar material. However, it is hoped that the straightforward step by step presentation will be a useful and ready reference for even the most experienced readers.

B. PURPOSE

The purpose of this Economic Analysis Handbook is to provide official NAVFAC guidance for the preparation of economic analyses for:

1. Proposed programs, projects and activities.

2. Program evaluation of ongoing activities.

The methodologies demonstrated herein should be applied in comprehensive and continuous management reviews of the cost and effectiveness of both proposed and ongoing projects.

The concepts of economic analysis and program evaluation constitute an integral part of the Planning, Programming, and Budgeting System of the Department of Defense (DoD), including Navy facilities investment and operations decisions. Economic implications are at all levels of authority, e.g., Headquarters, Command and installation. However, economic analysis and program evaluation serve different purposes.

Economic analyses are "pre-expenditure" analyses designed to assist a decision-maker in identifying the best new project/program to adopt. Program evaluations are "post-expenditure" analyses designed to evaluate ongoing approved projects/programs to ensure objectives will be attained in a cost effective manner, based on actual performance.

Submission of analyses at appropriate levels is prescribed by existing instructions. Project officers and managers should be prepared to demonstrate the costs and benefits of proposals and to submit detailed supporting analyses, when required.

The guidance contained in this handbook is consistent with the current version of the DoD Instruction (DODINST) 7041.3 series, "Economic Analysis and Program Evaluation for Resource Management," and the corresponding implementing Navy instructions (SECNAVINST 7000.14 series and OPNAVINST 7000.18 series). A listing of all relevant economic analysis policy documents (latest revisions and dates noted as of the time of publication of this handbook) is provided in Appendix C.

C. ECONOMIC ANALYSIS DEFINED

Economic analysis can be defined as a systematic approach to the problem of choosing how to employ scarce resources to achieve a given objective in an effective and efficient manner.

The basic premise of economic analysis is that for all proposals there are alternative choices or trade-offs for reaching an objective, even if one of the options is to maintain a status quo, or to do nothing. An economic analysis, also referred to as a benefit/cost analysis, systematically investigates the full implications (in terms of costs and benefits) of achieving an objective. This orderly, comprehensive presentation of alternatives allows the decision-maker to select the most cost effective alternative. An economic analysis accomplishes this by:

1. Focusing thinking (both formal and informal).

2. Surfacing assumptions (both hidden and presumed), and classifying their logical implications.

   and

3. Providing an effective communications vehicle for all considerations in support of the decision.

To do this, the economic analysis process, as prescribed in Section II, is a proven guide for making a complete economic analysis.

D. COMMONSENSE PRINCIPLES

The essence of economic analysis is a common sense approach to the very real problem of the efficient allocation of scarce resources. Economic analysis is a formalization of common sense input to decision-making consistent with three sound economic principles:

1. All reasonable alternative methods of satisfying a given program objective must be investigated.

2. Each alternative must be considered in terms of its full life cycle funding implications, as well as its full life cycle benefits.

3. Money has value over time as expressed by the price it commands. This fact is included in the analysis by expressing life cycle costs and benefits in terms of their "present value."

These three concepts are intuitively acknowledged by all of us in our day to day decisions. We consider them (at least in passing) when we buy a car, rent an apartment, buy a house or evaluate any other personal investment options. The Department of Defense economic analysis policy is merely a formalization of these three concepts, and if the analyst keeps this in mind, he will better understand the spirit as well as the form of DoD economic analysis policy.

E. MOTIVATION FOR ECONOMIC ANALYSIS

Economic analysis is a tool by which factors affecting a decision may be qualified and quantified to assist in the decision-making process. However, economic analysis is not a panacea. Economic analysis is not in itself a decision-making process; it is only an input to the decision-making process. The decision-maker must still interpret the results of the economic analysis along with other factors such as safety, health, morale, environmental impact and other constraints. In short, economic analysis is not a substitute for sound management judgment; rather, by systematically quantifying what is quantifiable, economic analysis does the following:

1. It allows the decision-maker to focus his judgment more sharply on the economic aspects of a decision.

2. It serves as documentation and visible evidence to authorities that economic factors bearing on the decision have been duly considered.

By postulating alternative ways of satisfying an objective and documenting all the costs and benefits, the economic impacts of alternative actions can clarify the "crystal ball" of management.

II. THE ECONOMIC ANALYSIS PROCESS

A. SIX STEPS OF ECONOMIC ANALYSIS

Proper performance of an economic analysis consists of six steps:

1. Define the Objective.
2. Generate Alternatives.
3. Formulate Assumptions.
4. Determine Costs and Benefits.
5. Compare Costs and Benefits and Rank Alternatives.
6. Perform Sensitivity Analysis.

These steps comprise the key elements of any economic analysis. Analytical considerations involved in each of these steps are described in the following pages.

STEP 1 - DEFINE THE OBJECTIVE

The single most important step in the analysis is the first step, defining the objective. Without a succinct statement of what is to be investigated, the analyst cannot possibly proceed in a meaningful way. This seemingly trivial step sets the tone and the level of objectivity for the whole analysis. As Aristotle wrote, "Well begun is half done."

For example, consider the case of major weapon system procurement. What is the purpose of the weapon system? Is it to be offensive or defensive? What level of coverage should it provide? To what contingencies should it be capable of responding? It should be clear that until the answers to these and other questions are known, the analyst cannot proceed with (or even conceive of) the economic analysis.

Fortunately, the problem of defining the objective usually lends itself to straightforward solution in the area of facilities procurement. Typical facilities planning objectives might be to:

1. Provide 1,000 square meters of administrative space.
2. Meet Environmental Protection Agency (EPA) pollution abatement requirements at a Naval activity.
3. Provide housing for 100 unaccompanied officers.

A well defined objective statement should incorporate, either explicitly or implicitly, a measurable standard of accomplishment. Note that Objective #1 explicitly states a measurable standard (1,000 square meters); Objectives #2 and #3 incorporate implicit standards.

The actual wording of the objective is critical in that it should reflect a totally unbiased point of view concerning methods of meeting the objective. For example, Objective #3 is a proper (unbiased) objective, but "Build Unaccompanied Officer Personnel Housing (UOPH) for

100 persons" is not. Unbiased statements of objective should always be used, and most importantly, kept in mind throughout the entire economic analysis process.

STEP 2 - GENERATE ALTERNATIVES

After formulating an unbiased statement of objective, the next step is to determine all feasible alternative methods of meeting that objective. Since the ultimate purpose of the economic analysis process is to assist the decision-maker in making resource allocation decisions, it is essential that all realistic alternatives be considered. Good decisions are extremely difficult (probably impossible) unless they are made with a full understanding of all relevant options.

Occasionally there will exist presumptive notions concerning the desirability of one or more options, or perhaps some administrative constraints (such as an upper limit on Military Construction (MILCON) dollars) which tend to exclude certain alternatives. Such conditions in no way obviate the necessity for the analyst to do a complete job. All reasonable and viable alternatives must be considered; otherwise, the value of the analysis is seriously undermined. Furthermore, consideration of all alternatives provides useful information about "impossible" alternatives.

For example, consider the situation in which the following two alternatives have been presented:

1. MILCON (1).

2. Commercial lease.

MILCON (1) is favored as being the lesser life cycle cost (present value) option. However, a third alternative, MILCON (2), has not been considered because its construction cost estimate was deemed too high. Upon further investigation, it is found that due to the unique features of this third alternative, operating and maintenance costs will be minimal -- so much so, in fact, that alternative 3 is <u>really</u> the lowest life cycle cost (present value) option. Should this alternative be brought to the decision-maker's attention?

The answer, of course, is <u>YES</u>. The decision-maker should evaluate all feasible alternatives. The decision-maker may still opt for alternative 1 (MILCON (1)), but this should be done with the knowledge that it is not the most cost effective solution. The decision-maker should know that he must be willing to pay a life cycle cost premium in order to choose an alternative which requires a smaller MILCON funding appropriation.

Alternatives which at first appear to be infeasible may, in fact, be feasible. Provision of military family housing overseas is an example. Formerly, foreign leases were limited by law to five years. An economic analysis was performed which indicated that a ten year leasing

period increased the present value of life cycle costs by only about 10%. Furthermore, renewing a five year lease to cover ten years results in a 70% greater life cycle cost than if the lease were originally written for ten years. As a consequence of this economic analysis, the U.S. Congress was successfully petitioned to change the law to permit ten year leasing in overseas areas.

STEP 3 - FORMULATE ASSUMPTIONS

The process of economic analysis deals with future expenditures and thus involves elements of uncertainty. The complete factual picture of an alternative under consideration may be impossible to construct and certain assumptions may be necessary in order to proceed with the analysis. When this is true, assumptions should be clearly indentified for what they are, and should be accompanied by a statement of the bases for them and (if possible) an estimate of their validity. The use of undocumented assumptions detracts from the credibility of an analysis. Frequently, the analyst must formulate assumptions even before reasonable alternatives can be generated. Thus, this step of the process may occur more than once in the course of preparing an analysis.

STEP 4 - DETERMINE COSTS AND BENEFITS

The analyst must investigate each alternative to determine all the costs and benefits occurring during the entire project life cycle. Costs, although often difficult to estimate, are at least easy to measure in terms of dollars. A detailed discussion of relevant costs and estimating methods is included in Section IV. Benefits, on the other hand, are often difficult to measure explicitly. Despite this inherent difficulty, it is incumbent upon the analyst to quantitatively assess the benefits associated with each alternative under consideration whenever possible. A detailed discussion of suggested techniques for benefit analysis is contained in Section V.

STEP 5 - COMPARE COSTS AND BENEFITS AND RANK ALTERNATIVES

This step is the essence of the economic analysis because it provides the tool for better management decision-making. In general, there are four possible configurations into which alternatives may fall:

1. EQUAL COSTS/EQUAL BENEFITS.
2. EQUAL COSTS/UNEQUAL BENEFITS.
3. UNEQUAL COSTS/EQUAL BENEFITS.
4. UNEQUAL COSTS/UNEQUAL BENEFITS.

Each of these configurations requires a different criterion for ranking. Configuration 3 rarely occurs in pure form in the facilities acquisition process, since the benefits attending different alternatives are rarely, if ever, truly equal. However, this unequal costs/equal benefits assumption is frequently an acceptable compromise with reality to facilitate the analysis process. When this assumption is made, the

analyst employs the techniques developed in Section III. Additionally, a qualitative statement explaining possible differing benefit should be included in the economic analysis documentation.

Frequently, however, the only valid assumption the analyst can make is that both the costs and benefits of alternatives are unequal -- configuration 4. When this is the case, the analyst must address both sides of the benefit/cost equation, employing the techniques described in Sections III and V.

STEP 6 - PERFORM SENSITIVITY ANALYSIS

Because uncertainties are always present, it is necessary to test the sensitivity of the analysis to dominant cost factors and assumptions in order to portray a complete picture to the decision-maker. Techniques of sensitivity analysis are discussed in Section VI.

Sensitivity analysis also provides feedback within the economic analysis process by indicating to the analyst which estimates and assumptions are in need of further refinement. Thus, economic analysis is an iterative process, as illustrated in Figure II-1, which summarizes the process.

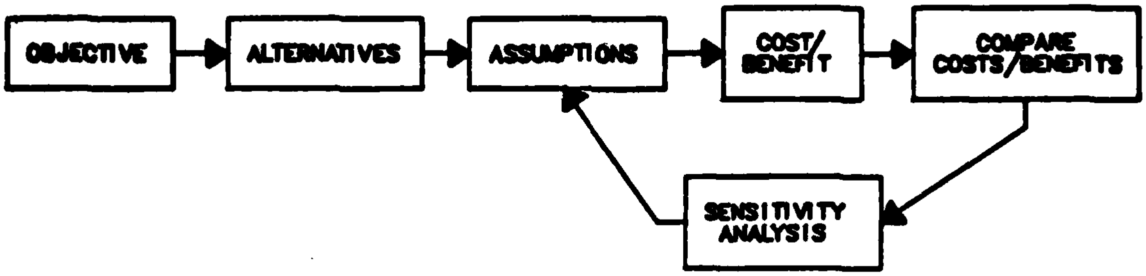


FIGURE II-1

When documenting an analysis, the analyst should ensure that all six steps of the process are addressed in the economic analysis submission.

B. CLASSES OF ECONOMIC ANALYSIS

Within the realm of the NAVFAC facilities acquisition process there are two distinct uses to which the process of economic analysis may be applied. Consequently, it is convenient to define two classes of analysis. Within each class, two types of economic analysis are defined. The classes are:

1. FUNDAMENTAL PLANNING ANALYSIS (FPA). In the Fundamental Planning Analysis (FPA), the analyst adopts the broadest possible perspective of his own Navy activity's facilities planning objectives. The analyst develops an unbiased definition of the precise planning objective and identifies all the feasible methods of accomplishing the objective. In general, these alternative methods will include MILCON as well as non-MILCON funding options, and the FPA is the appropriate forum for their evaluation. If the analysis indicates that a MILCON alternative is the most cost effective option available to the Navy, then the analysis further provides the formal economic justification and substantiation for a Navy request to Congress for MILCON project funds. (If analysis indicates that only one alternative is feasible, the analyst is required to document the thought process that led to this conclusion. In essence, a list of the alternatives which would fulfill the objective and proof of their infeasibility must be submitted as part of the facility study in lieu of an economic analysis. Only then can the premise that there is only one method of satisfying a facilities deficiency be fully supported.)

Accordingly, the FPA is an important document and should be prepared carefully and completely. Because there exist two broad categories into which Navy investment proposals fall, it is useful to define two types of analysis:

a. TYPE I: A Type I economic analysis (also referred to as a primary economic analysis) is one employed to help determine whether an existing situation or procedure should be changed in some way to take advantage of dollar savings available through some other situation or set of procedures. This type of analysis addresses the basic need and economic justification for some change to present conditions. A Type I analysis is principally concerned with the economics of projected dollar savings, since the operational requirement is already being met. A Type I analysis would justify a project which is economically advantageous because it permits the requirement to be met at a lower life cycle cost. The classic Type I analysis situation is that in which it is proposed that a significant investment be made now so that a reduction in annual costs over the life cycle relative to the status quo may be achieved. Some examples of Type I (primary) economic analyses are:

* Investment in additional insulation for existing buildings in order to lower heating and cooling costs.

* ‾xpansion of utility systems at berthing ‾rs to allow in-port ships to secure rnal power plants.

* Modernization of Naval Air Rework Facility (NARF) overhaul facilities to speed overhaul work, thereby decreasing the aircraft "pipeline" inventory requirements.

* Replacement of existing high maintenance cost facilities or equipment with new facilities which have lower maintenance costs.

b. TYPE II: A Type II economic analysis (also referred to as a secondary economic analysis) is one which is used once a deficiency or changed requirement has been identified to determine which of several planning alternatives (for example, new construction versus commercial lease) would most economically satisfy the deficiency. This type of analysis does not concern itself with the justification for the requirement but rather with the choice of alternative ways to satisfy a previously stated basic need or deficiency. A Type II analysis justifies a project in which economic considerations are secondary to military operational requirements. Since the requirement exists and is not currently being fulfilled, the Type II analysis is accomplished in order to provide a basis for the selection of the best alternative. Examples of Type II (secondary) situations are:

* Acquisition of land for a new communications center, either through lease or outright purchase.

* Correction of facility deficiencies through new construction versus rehabilitation of existing facilities versus conversion of other existing unused facilities.

* Providing housing for unaccompanied personnel either by construction of new Unaccompanied Enlisted Personnel Housing (UEPH) or by payment of Basic Allowance for Quarters (BAQ) or by lease construction of housing.

Additional discussion of the basic differences between Type I (primary) and Type II (secondary) economic analyses is appropriate to assure that budget submissions reflect those differences. Type I economic analyses are those which involve proposed savings over an existing mode of operation. Investments supported by Type I economic analyses must promise absolute cost savings over the present method of meeting a requirement.

Type II economic analysis, on the other hand, refers to a method of selection of the most economical alternative from a group of alternatives all designed to perform a function or satisfy a mission which is not justified on the basis of dollar savings. For example, an additional facility requirement may be justified due to expanded mission of an activity. The methods of satisfying the additional requirement are investigated through the Type II economic analysis. In this case, the economically preferable alternative does not result in an absolute cost saving; rather, it represents the least cost alternative relative to other possible alternatives.

Another way of stating the difference between Type I and Type II analysis is to point out the differing impact on the Navy's expense cash flow. Type I analyses always address a status quo among the alternatives they consider, while Type II analyses do not. Type II economic analyses are used to justify investments which initiate an expense stream, whereas Type I economic analyses justify investments intended to reduce an already existent cash flow. The difference between projects resulting in absolute cost savings (Type I - primary) and those resulting in increased cost levels but which represent relatively less costly solutions (Type II - secondary) is significant in the Navy budgeting system.

NOTE: SPECIAL CASES. Certain military construction projects can qualify for Exigent Minor MILCON (EMM) funding if the project investment cost will be amortized by savings within a three year period. Such projects must be supported by Type I economic analyses. Due to the special nature of EMM project documentation requirements, however, these analyses must adhere to special guidelines. A discussion of economic analyses supporting EMM projects appears in Appendix A. Special guidelines also apply to economic analyses in which energy costs are important, such as in documentation for Energy Conservation Investment Program (ECIP) projects. A discussion of these guidelines appears in Appendix B.

2. DESIGN ANALYSIS (DA). Once a decision has been made to procure a given facility via the MILCON funding route (this decision in general having been influenced by the results of a Fundamental Planning Analysis), it may be necessary to perform an economic analysis (usually Type II) examining significant MILCON design alternatives. Examples of such Design Analyses (DA) are the following:

* One-level versus multi-level construction.
* Wood siding versus concrete masonry units.
* Steel versus concrete.
* Double-glazed glass versus single-glazed glass windows.
* Alternative physical orientations of a proposed structure.
* Alternate heating and cooling systems for a building.
* R-19 versus R-30 insulation.

The procedures for preparation of the DA are identical to those of the FPA. Only the nature of the alternatives considered (design vs. planning) differs. From this point, this handbook will address the procedures for preparation of the Fundamental Planning Analysis (FPA) unless explicitly stated otherwise. The reader should bear in mind that, except for the nature of alternatives considered, all procedures apply to Design Analyses (DA) as well.

C. PREPARATION AND REVIEW RESPONSIBILITIES

Specific preparation and review requirements may vary from time to time as the needs of the Navy change. Accordingly, they are not delineated here. The reader is referred to the current issue of the following source directives for specific guidance. (A comprehensive list of Navy economic analysis policy instructions appears in Appendix C.)

Fundamental Planning Analysis (FPA)

1. NAVFACINST 11010.44 series, "Shore Facilities Planning Manual."

2. NAVFACINST 11010.32 series, "Military Construction Program Projects; preparation of supporting documents for."

Design Analysis (DA)

NAVFACINST 11010.14 series, "Project Engineering Documentation (PED) for Proposed Military Construction Projects."

For further clarification of the policy requirements in force at the publication date of this handbook, the following comments are offered:

Fundamental Planning Analysis (FPA)

1. Prepared by the Navy activity requesting funds for a given project.

2. Submitted as part of the Facility Study (DD Form 1391C) to the updated Military Construction Project Data (DD Form 1391) when these documents are required.

3. Reviewed by the cognizant NAVFAC Engineering Field Division (EFD).

4. Ultimately available as part of the project data reviewed by NAVFAC; the Shore Facilities Programming Board (SFPB); Office of the Comptroller, Department of the Navy (NAVCOMPT); and Congressional Armed Services and Appropriations Committees.

Design Analysis (DA)

1. Prepared by either the cognizant EFD or an architect/engineer firm as part of the project design documentation.

2. Ultimately available as part of the project design data for review by appropriate authority.

Notwithstanding these general guidelines, the reader is strongly urged to consult the directives mentioned above to determine current and specific economic analysis preparation, submission, and review requirements.

III. BASIC ECONOMIC ANALYSIS TECHNIQUES

The techniques addressed in this section relate to the fifth of the six fundamental steps in economic analysis, namely the systematic comparison of costs and benefits. The notions developed below will be primarily cost oriented, because costs are almost always easily quantifiable in terms of dollars. It should be borne in mind, however, that these techniques are no less applicable to benefits which are expressible in terms of dollars. (For a discussion of benefit measurement and comparison, refer to Section V.)

Subsections III-A, III-B, and III-C, which consider cash flow diagrams, economic life, and interest and present value, respectively, are preliminary in nature. The cash flow diagram is a graphical convention which is used liberally throughout this handbook. Economic life and present value are fundamental concepts whose understanding is prerequisite to the general techniques developed in the remainder of this section: net present value comparison (III-D), the savings/investment ratio (III-E), and equivalent uniform annual cost (III-F).

A. CASH FLOW DIAGRAMS

The cash flow diagram is a pictorial technique for representing the magnitudes and timing of all costs associated with a given economic alternative. It is customary to draw a cash flow diagram for each alternative being considered in an economic analysis.

Figure III-1 shows a generalized cash flow diagram with a typical pattern of life cycle costs. The horizontal line represents a time axis. The choice of time unit is arbitrary, but the scale is usually graduated in years. Costs are represented by vertical arrows whose lengths are proportional to the cost magnitudes, and whose locations on the time line indicate when they occur.

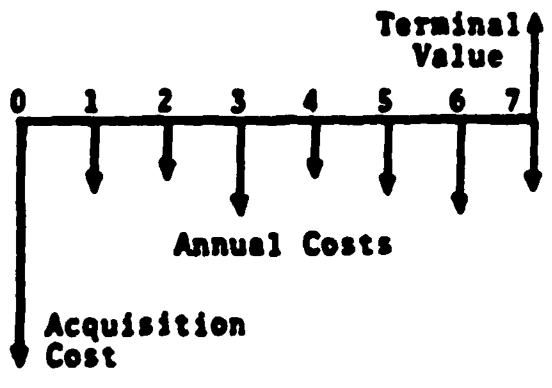


FIGURE III-1

In Figure III-1, the long arrow on the left (Time Zero) represents the acquisition or start-up cost; the shorter downward arrows (Years 1-7) represent costs incurred from year to year, as, e.g., operating costs, maintenance costs, and isolated one-time costs.

The upward arrow at the right (Year 7) represents the terminal or residual value of assets on hand at that time. Because terminal value is to be netted against the total life cycle cost, it acts to offset other costs, and is drawn upward. (In some cases terminal value might actually be negative. This would be true, e.g., if dismantling or demolition costs exceeded scrap or salvage value. Here, terminal value would be a positive cost represented by a downward arrow. For a more complete discussion of terminal value, see Section IV.)

B. ECONOMIC LIFE

Implicit in the specification of the costs represented in Figure 1 is the period over which they are incurred. The seven year time frame in that figure is referred to as the economic life of the alternative. In general, the economic life of a proposal (i.e., alternative) is the period of time during which it provides a positive benefit to the Navy. The specific factors limiting the duration of economic life are these:

1. The mission life, or period over which a need for the asset(s) is anticipated;

2. The physical life, or period over which the asset(s) may be expected to last physically;

3. The technological life, or period before obsolescence would dictate replacement of the existing (or prospective) asset(s).

Explicit guidelines are supplied below for several categories of investment. Generally, the economic life of an alternative should be taken as the least of the above three time parameters.

It should be noted that there may be a significant period (i.e., lead time) between the initial investment expenditure and the beginning of the economic life. Economic life starts only when the alternative begins to yield tangible benefits to the Navy. In the case of occupiable shore facilities, for example, the beginning of economic life coincides with the date of beneficial occupancy.

The economic lives of the various possible project alternatives will govern the time period to be covered by the economic analysis. In general, the economic lives of all alternatives should be set so that they start in the same year and, where possible, extend over the same period of time. The case of unequal economic lives requires special analytical treatment and will be discussed in Subsection III-F.

ECONOMIC LIFE GUIDELINES. To provide a basis for comparison between competing projects, economic lives are established for the general investment classifications listed below. These are guidelines to be used in the absence of better information. However, due to the constraints of mission life and technological life, the economic life chosen should not exceed the applicable figure below. (The mechanics of discounting also militate against taking economic lives in excess of 25 years. See Subsection VI-C. Discounting techniques are developed in Subsection III-C). If a shorter life is selected, the reasons for the choice should be documented. (Guidelines for facility categories are based upon DOD 4270.1-M, "DOD Construction Criteria Manual.")

1. ADP EQUIPMENT . . . . 8 years

2. BUILDINGS

   a. Permanent . . . . 25 years

   b. Semipermanent, non-wood . . . . . 25 years

      Semipermanent, wood . . . . 20 years

   c. Temporary or Rehabilitated . . . 15 years

3. OPERATING EQUIPMENT . . . . 10 years

4. UTILITIES, PLANTS, AND UTILITY DISTRIBUTION SYSTEMS . . . . 25 years

   (This category includes investment projects for electricity, water, gas, telephone, and similar utilities.)

5. ENERGY CONSERVING ASSETS

   a. Insulation, solar screens, heat recovery systems, and solar energy installations . . . . 25 years

   b. Energy Monitoring and Control Systems . . . . 15 years

   c. Controls (e.g., thermostats, limit switches, automatic ignition devices, clocks, photocells, flow controls, temperature sensors, etc.) . . . . 15 years

   d. Refrigeration compressors . . . . 15 years

C. INTEREST AND PRESENT VALUE

Money is a productive commodity, and as such it commands a price for its use. This price is called interest. Interest is customarily expressed as a percent or decimal, representing the fractional amount of a loan the borrower must pay the lender within a specified interval of time, usually one year. The specific analytical mechanism is developed below.

COMPOUND INTEREST, ONE YEAR. Suppose an amount of money P is lent today at an annual interest rate i. The amount P originally loaned is called the principal. Further suppose that the loan is subject to the understanding that it is to be repaid at the end of one year. At that time, the borrower will have to return to the lender not only the original amount P, but an additional amount $P \cdot i$. The surcharge Pi is the price the borrower must pay for the use of the lender's money P during the year the loan is outstanding. The total amount F returned to the lender is thus

$$F_1 = P + Pi = P(1 + i). \qquad ...(III-1)$$

COMPOUND INTEREST, TWO YEARS. Suppose the above loan is to be repaid at the end of two years instead of one. The amount which would have been paid at the end of Year 1 is $P(1 + i)$, as we have just seen. This becomes the principal during the second year, i.e., the interest has been compounded at the end of Year 1. (Throughout the remainder of this discussion, it is assumed that interest is compounded every year.) The amount repaid at the end of Year 2 is

$$F_2 = (P(1 + i))(1 + i) = P(1 + i)^2. \qquad ...(III-2)$$

(In equation (III-2), $P(1 + i)$ takes the place of P in equation (III-1).)

EXAMPLE III-1: Clark Snark opens a savings account at the Ninth National Bank with an initial deposit of $500. If the bank pays interest on savings at the rate of 5% per year, what will be the balance in Mr. Snark's account in two years' time? (Assume that no deposits or withdrawals are made in the interim.)

SOLUTION: Note that this is in fact a loan transaction; the bank pays Mr. Snark interest for the two years it has the use of his money. Here P = $500, i = 0.05, and so by equation (III-2),

$$F_n = \$500(1.05)(1.05) = \$500(1.1025)$$
$$= \$551.25$$

COMPOUND INTEREST, N YEARS. By successive repetition of the reasoning used in the two year case, if an amount P is lent today at an annual interest rate i, the total amount repaid to the lender by the borrower at the end of n years is

$$F_n = P(1 + i)^n. \quad \text{...(III-3)}$$

The behavorial significance of equation (III-3) outweighs its mathematical significance. In the money market, with a prevailing interest rate i, the lender is willing to exchange (or, more precisely, to forgo) P dollars today in return for $P(1 + i)^n$ dollars n years from today. That is, the future worth to the lender of P dollars today is $P(1 + i)^n$ dollars n years from today. The borrower, on the other hand, is willing to secure the use of P dollars today by agreeing to pay $P(1 + i)^n$ dollars n years from today. In this situation, the lender and borrower complement one another, but to each, P dollars today and $P(1 + i)^n$ dollars n years from today are equivalent.

Whether viewed from the standpoint of the borrower or the lender, equation (III-3) is addressed to the problem of determining the future value of P dollars today. Another perspective is possible, however, as the following illustration shows.

EXAMPLE III-2: Mr. and Ms. Barclay plan to take a luxury world cruise in 3 years (after the date of Mr. Barclay's retirement). The fare charged by Cunard Lines is $11,000/couple. To finance the trip, Mr. Barclay plans to open a passbook account at Fly-By-Night Savings and Loan, which pays interest at the rate of 6% per year. How much must Mr. Barclay deposit today, if the balance in his account is to cover the cost of the trip 3 years from today? (Assume that no other deposits or withdrawals will be made in the meantime, and that the Cunard fare will still be $11,000/couple in 3 years' time.)

SOLUTION: Equation (III-3) still applies, but here it is necessary to solve for the unknown P:

$$F_3 = \$11{,}000, \quad i = 0.06, \quad n = 3 \text{ years;}$$

$$F_3 = P(1 + i)^3 \text{ yields } \$11{,}000 = P(1.06)^3 = P(1.191)$$

yields $$P = \frac{\$11,000}{1.191} = \$9,235.94$$

In the above example, a service costing $11,000 three years from today could be secured by setting aside $9,235.94 today. In this sense, $9,235.94 today is equivalent to $11,000 three years from today. Another way of stating it is that, relative to an interest rate of 6%, the present value of $11,000 three years from today is $9,235.94.

Problems like Example III-2 may be approached systematically by solving equation (III-3) for the principal P. Doing so, we obtain

$$P.V. = F_n\left[\frac{1}{(1 + i)^n}\right] \qquad \text{...(III-4)}$$

Here F_n represents the dollar amount of a cash flow occurring n years in the future, i is the interest rate, and the notation "P.V." has been substituted for "P" to stress the fact that it represents a cash equivalent in today's dollars (i.e., a present value). The quantity $1/(1 + i)^n$ within brackets, which is less than unity, reduces the future cash flow F_n to its present value equivalent P.V., and is thereupon referred to as a discount factor.

The concepts developed in this subsection culminate in two general observations:

1. Because of its productivity, there is a time value associated with money. A dollar ten years from today is not the same as a dollar five years from today or a dollar today. An investor needs to take this time value of money into account when analyzing an investment proposal involving expenditures and receipts at varying points in time. Specifically, in order for a meaningful comparison to be made, such costs and returns should be converted into equivalent costs and returns occurring at a single point in time. The point in time usually chosen is the present, and the mechanism of conversion is equation (III-4) with an appropriate interest rate i.

2. Equations (III-3) and (III-4) apply in a much broader context than a simple monetary transaction between borrower and lender. The most general interpretation of i is that of a rate of return confronting the

investor (or borrower, as the case may be), whether that investor be an individual, a corporation, or an entire economy considered as an aggregate of individuals, corporations, and government. The problem of determining a weighted average rate of return (or, in the corporate context, the weighted average cost of capital) becomes more ramified as the portfolio of the investor becomes more diversified. Studies performed to ascertain the average rate of return for the private sector of the U. S. economy have yielded results in the approximate range 7-13%. One notable study ("Measuring the Opportunity Cost of Government Investment" by J.A. Stockfish, IDA Research Paper P-490, March, 1969, discussed in Section VII) has produced a result of approximately 10.4%, near the middle of this range. Accordingly, the figure of i = 10% (commonly called the "discount rate" because of its impact in equation (III-4)) has been specified for most Government investments by Office of Management and Budget (OMB) Circular No. A-94 and for most DoD investments by DODINST 7041.3. (An exception is the case of projects whose costs or cash benefits extend over periods of 3 years or less. Here discounting is not required. This and other exceptions are detailed in DODINST 7041.3.) The rationale for adopting the private sector rate of return as the discount rate for analyzing Government investment proposals turns on the notion that Government investments are funded with money taken from the private sector (preponderantly via taxation), are made in the ultimate behalf of the private sector (i.e., the individuals comprising it), and thus bear an implicit rate of return comparable to that of projects undertaken in the private sector. In this interpretation, 10% measures the opportunity cost of investment capital forgone by the private sector.

D. DISCOUNT FACTORS; NET PRESENT VALUE (NPV) COMPARISONS (TYPE II ECONOMIC ANALYSES)

As the preceding subsection implies, in economic analyses of Navy investment proposals the present values of costs (and, where applicable, benefits) are to be calculated before economic comparisons are made. This computation of present values (or, as it is commonly referred to, discounting) is to be done by means of formulae such as equation (III-4), with i taken as 0.1 (10%).

To streamline the computational task of preparing economic analyses, it is convenient to prepare a list of discount factors for purposes of reference. Table III-1 gives a list of such factors for Years 0-3. These were derived by taking i = 0.1 in the bracketed factor $1/(1 + i)^n$ of equation (III-4).

TABLE III-1
10% PRESENT VALUE FACTORS

Years from Today (n)	P.V. Factor
0	$\frac{1}{(1.1)^0} = 1.000$
1	$\frac{1}{(1.1)^1} = 0.909$
2	$\frac{1}{(1.1)^2} = 0.826$
3	$\frac{1}{(1.1)^3} = 0.751$

In Appendix E of this handbook, a list of present value factors is given for Years 1-30 in Table A. These factors will be adequate for proposals having an economic life of 25 years and a lead time of up to 5 years. A comparison of Table A and Table III-1 shows that none of the factors for Years 1-3 is in agreement between the two. This discrepancy, as indicated by the comparison in Table III-2, is explained by the fact that the Table A factors are based on continuous compounding, which is a consequence of the assumption that cash flows are spread throughout the one year period, while the factors developed in Table III-1 assume discrete cash flows at the ends of years.

TABLE III-2

DISCOUNT FACTOR COMPARISON

YEAR	END OF YEAR FACTOR	CONTINUOUS COMPOUNDING FACTOR
1	0.909	0.954
2	0.826	0.867
3	0.751	0.788
4	0.683	0.717

Consider a $1 expenditure made during Year n in a continuous stream. As an approximation to this continuous uniform cash flow, let year n be divided into k equal time intervals, each of length 1/k years, with $1/k being expended at the end of each interval, as shown in Figure III-2.

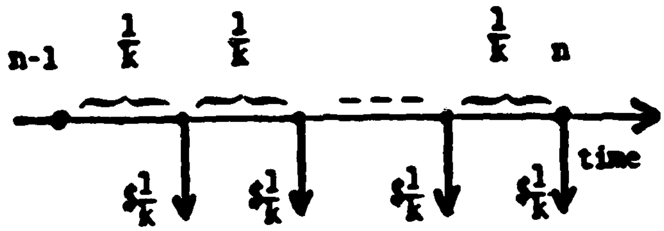


FIGURE III-2

Instead of compounding annually as before, compounding is done at each interval. Now let us increase the number of intervals so that each interval becomes shorter and the amount expended at the end of each interval becomes smaller. At the limit as the number of intervals approaches infinity, compounding becomes continuous and cash flow becomes uniformly continuous. It is this situation that is modelled when continuous compounding factors are used. The continuous compounding factors shown in Table III-2 were derived using a 10% effective annual discount rate.

The rationale for using continuous compounding factors instead of end of year factors is essentially twofold:

1. After the initial investment (acquisition) cost, many of the annual costs associated with a project do not occur at a single point in time, but rather are spread throughout the year. This is typically true, e.g., of operating costs and salaries, both military and civilian. Such costs are best approximated by cash flows occurring throughout the year rather than at year's end. In this case the use of continuous compounding factors is clearly appropriate.

2. The exact times of occurrence of one-time costs in the out-years of an economic life may not be known with certainty. In the absence of more specific information, there is no reason to assume that these costs will occur only on anniversaries of acquisition; they might occur at any point in the year. By applying continuous compounding factors to such costs, in the long run we should expect errors on the low side to occur about as often as errors on the high side, with a resultant offsetting effect.

Reference is again made to the cash flow diagram of Figure III-1. Although the cash flows are represented as occurring at the ends of years, they are presumed to have occurred merely at some time during (or throughout) their respective years. The arrow directly beneath the number 3 on the time line, for example, is understood to signify all costs occurring during the third year. This convention shall be adhered to throughout this handbook.

NOTE: For the sake of simplicity, continuous compounding factors are sometimes represented as being averages of consecutive end of year factors. Computing averages of end of year factors will approximate, but not duplicate, continuous compounding factors.

The mechanics of present value calculations are now illustrated by several examples.

EXAMPLE III-3: Compute the total net present value (NPV) cost corresponding to the cash flow diagram of Figure III-3. Assume Time Point 0 to be the present.

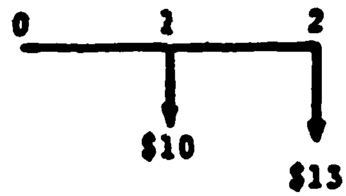


FIGURE III-3

SOLUTION: Nominally, the total cost would be \$10 + \$13 = \$23. If the time value of money is taken into account, the approach is exactly the same, except that the present values of the \$10 and \$13 must be computed before they are added. Application of the first and second year factors from Table A (Appendix E) yields:

$$\text{Total NPV Cost} = \$10(0.954) + \$13(0.867)$$

$$= \$9.54 + \$11.27$$

$$= \$20.81$$

Here, \$20.81 represents the equivalent in today's dollars of \$10 flowing during the next year plus \$13 flowing during the following year.

EXAMPLE III-4: Compute the total NPV cost for the uniform recurring \$10 cash flows shown in Figure III-4.

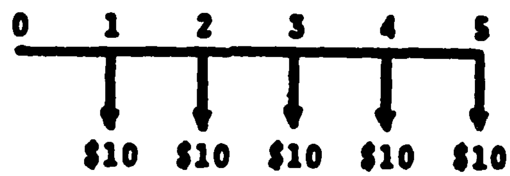


FIGURE III-4

SOLUTION: Applying the Table A factors for Years 1-5 leads to the series of calculations shown below:

$$\begin{aligned}\text{Total NPV Cost} &= \$10(0.954) + \$10(0.867) + \$10(0.788) \\ &\quad + \$10(0.717) + \$10(0.652) \\ &= \$9.54 + \$8.67 + \$7.88 + \$7.17 + \$6.52 \\ &= \$39.78\end{aligned}$$

The generic approach used in Example III-4 above entailed five multiplications followed by the addition of five numbers. The work can be simplified somewhat by factoring the recurrent \$10 from each term to get

$$\text{Total NPV Cost} = \$10(0.954 + 0.867 + 0.788 + 0.717 + 0.652).$$

This effectively reduces the problem to one of finding the sum of the first five Table A factors and then performing a single multiplication.

The task would be simplified still further if cumulative sums of Table A factors were already tabulated somewhere for reference. This is precisely what has been done in Table B of Appendix E (the right hand column on the same page as Table A). In that table, the first year cumulative factor is the same as that in Table A (0.954); the second year factor, 1.821, is the sum of the first two Table A factors (0.954 and 0.867); and in general, the nth year Table B factor is the sum of the first n Table A factors.

Applying the 5th year Table B factor to the recurring cash flows of Example III-4, we have

$$\text{Total NPV Cost} = \$10(3.977) = \$39.77$$

immediately. (The discerning reader has no doubt noticed the one cent discrepancy between the answers obtained by the Table A method and the Table B method. This is because the Table B factors have been computed from mathematical formulae rather than as simple accumulations of Table A factors, and there are occasional deviations in the third decimal place due to roundoff. Formulae for these factors are also shown in Appendix E.)

Table B factors are useful because the annual costs of an economic alternative may often be assumed (estimated) to be *uniform recurring* costs in constant dollar terms. (See Subsection IV-G for an explanation of constant dollars.) A general rule for the application of cumulative discount factors may be stated as follows:

> Rule 1: To find the total net present value of a series of uniform recurring cash flows beginning in Year 1 and continuing through Year n, multiply the amount of the annual payment by the nth year factor from Table B, Appendix E.

EXAMPLE III-5: Compute the total NPV cost for the uniform recurring cash flows of Figure III-5.

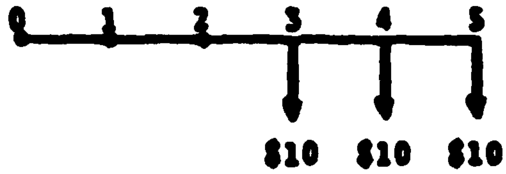


FIGURE III-5

SOLUTION: This problem may of course be solved in hammer and tong fashion by applying the third, fourth, and fifth year Table A factors in turn. Unfortunately it is not possible to use Rule 1 above, because the cash flows do not begin in Year 1 -- here they begin in Year 3. Table B factors may still be applied, however, by considering the cash flows of Figure III-5 to be the difference between a five year uniform recurring series and a two year uniform recurring series, both starting in Year 1. Invoking Rule 1 twice, we have

$$\begin{aligned}\text{Total NPV Cost} &= \$10(3.977) - \$10(1.821)\\ &= \$10(3.977 - 1.821)\\ &= \$10(2.156)\\ &= \$21.56\end{aligned}$$

The method used to solve Example III-5 may be stated as a second general rule:

> RULE 2: To find the total net present value of a series of uniform recurring cash flows beginning in Year m and continuing through Year n, multiply the amount of the annual payment by the difference between the nth and (m-1)st year factors from Table B, Appendix E.

If the economic analyst is not confronted by the problems of benefit measurement and comparison, he may determine an optimum choice between alternatives solely by using the techniques illustrated in Examples III-3 through III-5. In such a situation, the following two conditions must hold:

1. All alternatives have the same economic life.

2. All alternatives provide roughly the same level of benefits over their common economic life.

The reader will recall that in Section II a Type II (secondary) economic analysis is defined as one addressed to a deficiency or changed requirement. If a Type II analysis satisfies the two assumptions above, then total NPV costs are to be computed for each alternative, and that alternative having the least present value cost is to be preferred. This criterion of choice should be recognized as a simple extension of the reader's intuition and experience, refined to take into account the time value of money.

EXAMPLE III-6 (OPERATION SECONDARY): The cash flow diagrams of Figures III-6A and III-6B represent two feasible alternatives to be undertaken in Operation SECONDARY. Using the cost information shown, calculate the total NPV cost for each alternative and make a recommendation on the basis of your results.

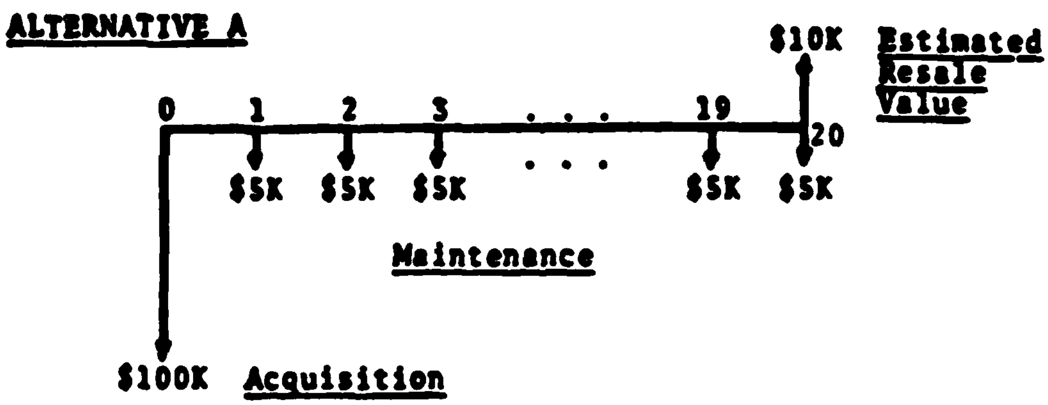


FIGURE III-6A

ALTERNATIVE B

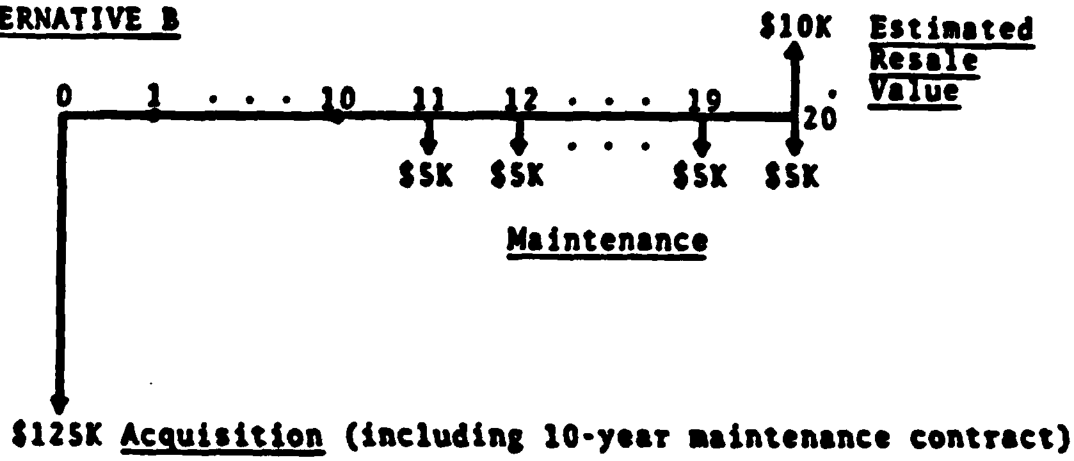


FIGURE III-6B

SOLUTION:

ALTERNATIVE A

Project Year(s)	Cost Element	Amount One-time	Amount Recurring	Discount Factor	Discounted Cost
0	Acquisition	$100K		1.000	$100.0K
1-20	Maintenance		$5K	8.933	$ 44.7K
20	Resale	($10K)		0.156	($ 1.6K)

TOTAL NPV COST: $143.1K

ALTERNATIVE B

Project Year(s)	Cost Element	Amount		Discount Factor	Discounted Cost
		One-time	Recurring		
0	Acquisition	$125K		1.000	$125.0K
11-20	Maintenance		$5K	8.933 -6.447 2.486	$ 12.4K
20	Resale	($10K)		0.156	($ 1.6K)

TOTAL NPV COST: $135.8K

REMARKS:

1. The tabular array of NPV cost computations shown for each option resembles that of Format A, Appendix D. In a formal submission, a complete Format A would normally be prepared for each alternative of a Type II economic analysis.

2. Alternative B is to be preferred because of its lower NPV cost ($135.8K vs. $143.1K).

3. The acquisition costs for each alternative are shown to occur at Time Zero. This establishes the time reference point for present value calculations; the discounting of all other costs in both alternatives brings them back to this same baseline. Thus, the acquisition costs themselves remain undiscounted (or multiplied by a discount factor of 1.000, which amounts to the same thing.) Note that Time Zero may be a future point in time; it need not be the present. In this case, the dollars in the NPV comparisons are, strictly speaking, not today's dollars. This does not violate the consistency of the cost comparison, however, because the discounting still translates all costs to the same point in time. (Another convention which is sometimes used is to treat acquisition cost as occurring in Year 1 and to discount it accordingly. Recurring annual costs then commence in Year 2. The "project years" of an economic alternative need not coincide with calendar years or fiscal years.)

4. In the present value calculations, a Table B factor was used for the recurring uniform series of maintenance costs in Alternative A, and a difference of Table B factors was applied to the deferred recurring uniform series of costs in Alternative B.

5. In this example, the anticipated resale value acts as a terminal value. It is enclosed in parentheses because it represents a negative cost. As such, its present value is to be netted against the NPV one-time and recurring costs in each alternative.

E. SAVINGS/INVESTMENT RATIOS; PAYBACK PERIODS (TYPE I ECONOMIC ANALYSES)

Economic analysis is directed toward the problem of finding the optimal means of satisfying a requirement, given that more than one alternative course of action exists. As we have seen, the requirement addressed by a Type II economic analysis is unresolved, that is, unsatisfied at the time the analysis is performed. This situation is indeed typical; the vast majority of all economic analyses prepared in support of the Military Construction Program are Type II.

Another possibility exists, however. It may be that a given requirement is already being met at the present time, but a better solution is perceived. In the context of economic analysis, "better" specifically refers to a proposed alternative whose total NPV cost is lower than that of the existing alternative (the status quo) over the same period (project life). In such a case, the justification for implementing the proposed alternative is primarily economic, and the analysis supporting the proposal is referred to as a Type I (primary) economic analysis (for examples of possible situations giving rise to Type I economic analyses, see Subsection II-B.)

Although it would be possible to demonstrate the economy of a proposed alternative over the status quo by a simple comparison of total NPV cost, another technique is preferred for Type I analyses. This is the computation of a savings/investment ratio (SIR). The use of SIR's allows a comparison of the "profitabilities" of various Type I military construction projects against each other.

Consider the general situation depicted in Figure III-7A and Figure III-7B. Cash flow Diagram A represents the status quo and Diagram B, the proposed alternative. Both extend over an economic life of N years. The absence of a startup cost in Diagram A suggests an already existent, ongoing alternative.

A. STATUS QUO

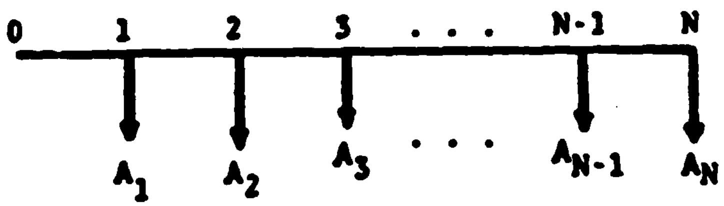


FIGURE III-7A

B. PROPOSED ALTERNATIVE

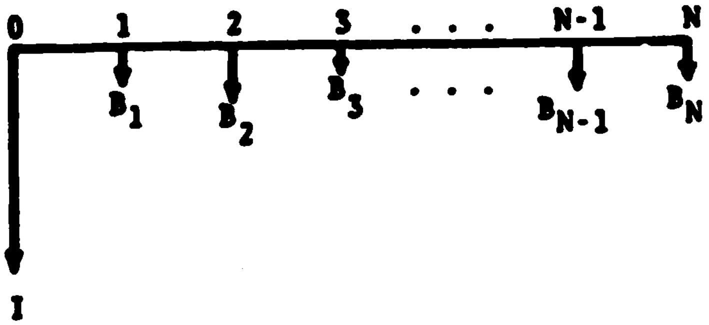


FIGURE III-7B

The crucial question is the following: Are the recurring cost savings of B relative to A sufficient to warrant the investment cost I that would be necessary to implement Alternative B? By savings is here meant the reduced amount of annual expenditure resulting from replacement of the status quo by the proposed alternative. In Figure III-7, the total net present value savings (of Alternative B relative to A) are:

$$P.V.(S) = P.V.(A_1 - B_1) + P.V.(A_2 - B_2) + \ldots + P.V.(A_N - B_N) \quad \ldots \text{(III-5)}$$

where S denotes savings and the notation P.V. means "present value of." The savings/investment ratio is therefore:

$$SIR = \frac{P.V.(S)}{I} \quad \ldots \text{(III-6)}$$

Clearly, Alternative B should not be undertaken unless the SIR exceeds unity (i.e., unless future discounted savings more than offset the initial investment cost).

Equation (III-6) captures the essence of the savings/investment ratio idea, but the situation can become more ramified, depending on the nature and timing of the cost elements involved. For example, if the

investment I associated with the proposed Alternative (B) is to be spread out over more than one year, the <u>total net present value</u> of I should be inserted into the SIR, yielding

$$SIR = \frac{P.V.(S)}{P.V.(I)} \qquad \text{...(III-6a)}$$

If Alternative B also includes a terminal value T, the present value of T should be netted against the investment I as follows:

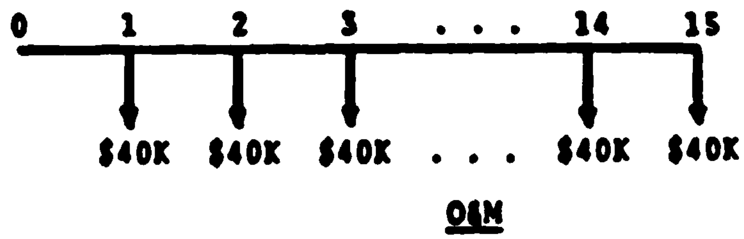
$$SIR = \frac{P.V.(S)}{P.V.(I) - P.V.(T)} \qquad \text{...(III-6b)}$$

The presence of other singular cost elements, such as the value of assets replaced or a refurbishment cost necessary to sustain the status quo, would necessitate still further refinements.

Fortunately, it is not necessary to determine a separate SIR formula for each distinct configuration of cost elements. Appendix D displays a Format A-1 to be used in the preparation of all Type I economic analyses. Items 7-22 of this format lead the analyst (or reviewer) to the correct SIR via a logical, step by step procedure which is valid for the most general case possible, and hence for any special case as well.

<u>EXAMPLE III-7 (OPERATION PRIMARY):</u> The cash flow diagrams of Figure III-8 represent the status quo and a proposed alternative in Operation PRIMARY. Using the cost information shown, calculate a savings/investment ratio for Alternative B relative to Alternative A and so determine if it is recommendable.

ALTERNATIVE A (Status Quo)



<u>FIGURE III-8A</u>

ALTERNATIVE B (Proposed)

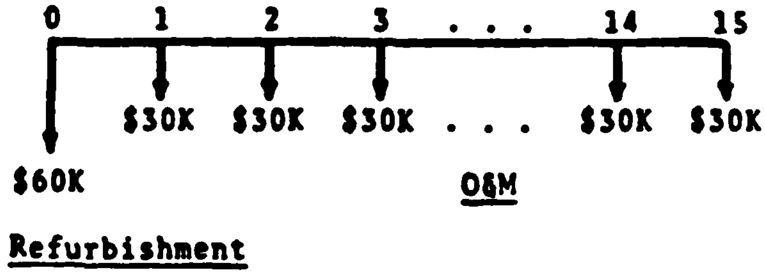


FIGURE III-8B

SOLUTION:

Project Year(s)	Recurring Costs		Diff. Cost	Discount Factor	Disc. Diff. Cost
	Present	Proposed			
1-15	$40K	$30K	$10K	7.980	$79.8K

TOTAL P.V. SAVINGS: $79.8K

TOTAL INVESTMENT: $60K

$$SIR = \frac{\$79.8K}{\$60.0K} = 1.33$$

REMARKS:

1. Due to the simplicity of Example III-7, the stepwise SIR calculation of Format A-1 (Appendix D) has not been reproduced above. The tabular array of recurring costs, however, resembles that prescribed by Format A-1. In that array, the Differential Cost (4th column) represents the undiscounted annual savings of the proposed alternative relative to the status quo, and the Discounted Differential Cost (extreme right hand column) represents the total discounted savings over the 15 year life.

2. Because the SIR in this example exceeds unity, implementation of Alternative B (in place of the status quo) is indicated. A SIR of less than 1.0 would have revealed that the present value savings were not sufficient to amortize the investment cost of Alternative B.

3. In a Type II analysis such as that of Example III-6 (previous subsection), a Format A is prepared for each alternative. For the Type I analysis, however, a Format A-1 is prepared for each alternative to the status quo. If there is more than one alternative to the status quo, then the one with the highest SIR should be selected on economic grounds, provided that the SIR exceeds unity.

4. Note the application of a cumulative (Table B) factor to the annual differential cost ($10K). This is possible because the annual savings are uniform. For the more general case in which they are not, individual Table A factors would have to be applied to each year's savings, and the results summed to obtain the total discounted savings.

5. Suppose the refurbishment were to take approximately one year to complete. Then savings would not begin until Project Year 2, and the economic life would occupy Project Years 2-16 instead of 1-15. The savings/investment ratio would be

$$\text{SIR} = \frac{\$10K(8.209 - 0.954)}{\$60K} = \frac{\$10K(7.255)}{\$60K} = 1.21,$$

in contrast to the previously computed result (SIR = 1.33). As we might expect, the one year delay in realization of savings makes the project less attractive economically.

PAYBACK PERIOD. Supplementary data for military construction projects supported by Type I economic analyses includes a discounted payback period. "Payback" is achieved when total accumulated present value savings are sufficient to offset (i.e., amortize) the discounted investment cost of a proposed alternative to the status quo. The payback period is simply the total elapsed time between the point of initial investment and the point at which the cumulative value of savings equals the value of the investment.

The concept of a payback period is intuitively easier to grasp than that of a savings/investment ratio. Also, the economic connotation of a payback period is not affected by the duration of the project's economic life. (For example, a 4.5 year payback period means the same thing whether the economic life is 10 years or 25 years, but a SIR of 2.0 does not; for a given SIR, the shorter the economic life the more attractive the project.) This concept is graphically illustrated by Figure III-9, which shows the cumulative present values of investment and savings for Operation Primary over the economic life. Payback occurs at the intersection of the two curves.

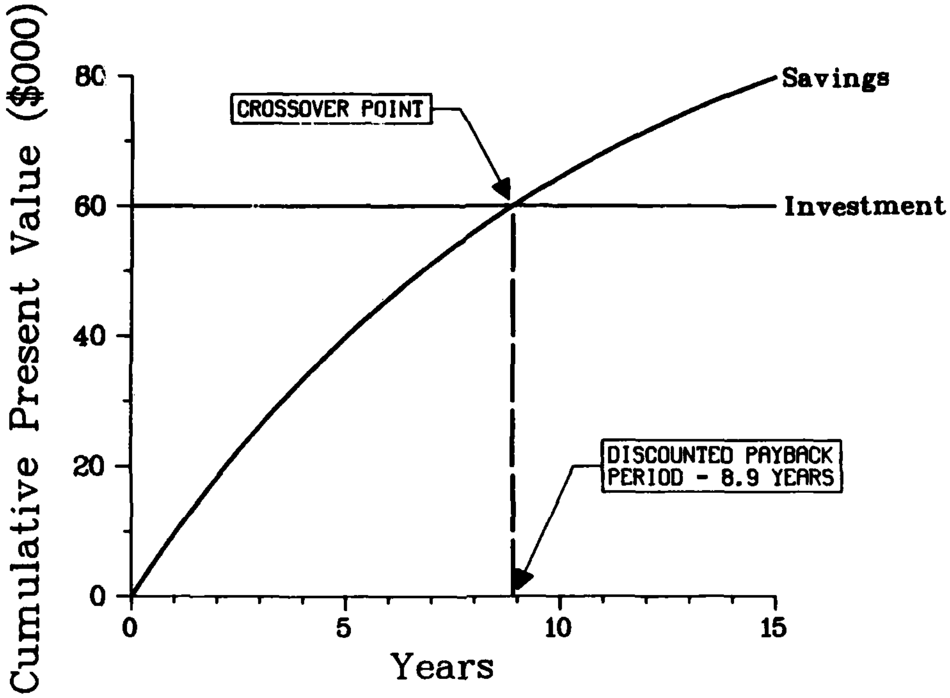


FIGURE III-9

The weakness of the payback period lies in its failure to address cash flows beyond the period necessary to recover investment costs. If significant one-time costs are to occur after the estimated point of payback (e.g., major repair or overhaul costs, or terminal site restoration costs), the payback period will tend to overstate the economic attractiveness of the proposed project.

For a given economic life, Table C (Appendix E) may be used to convert the savings/investment ratio to the corresponding payback period in years, provided future savings accumulate in equal amounts each year. If the SIR or economic life in a specific economic analysis does not exactly match the figures shown in Table C, straight-line interpolation/extrapolation may be used to estimate the investment payback period.

Table C should not be used if:

1. There are significant one-time costs in the out-years of either alternative (i.e., status quo or proposal);

2. An appreciable lead time intervenes between initial investment and the beginning of the savings stream; or

3. The standard 10% discount factors in Tables A and B, Appendix E, are not used in the present value calculations. (For example, escalated-discount factors from Appendix F might be used if anomalous cost escalation is expected. See Section VII.)

For exceptions 2 and 3 above, special techniques can be employed to determine the discounted payback period. These techniques are illustrated by Examples VII-9 through VII-11 in Subsection VII-D. (In cases where only exception 2 applies, the formula for the discounted payback period with lead time, shown in the back of Appendix E, may be applied.) More generally, the payback period can always be estimated empirically by accumulating the year by year discounted savings until the total exceeds the discounted investment cost, and noting in which project year this occurs.

EXAMPLE III-8: Estimate the discounted payback period for the Type I economic analysis of Example III-7.

SOLUTION: Here, the economic life is 15 years and the SIR was found to be 1.33. Interpolating between the values 9.23 and 8.22 in Table C, we find the approximate payback period to be 8.93 years.

REMARKS:

1. It is permissible to use Table C in Example III-8 because the annual cost savings ($10K) are uniform and no lead time is assumed.

2. Observe that the estimated payback period (8.93 years) was found to be less than the economic life (15 years). This we should expect, since the SIR of 1.33 indicates that the project "more than pays for itself" within a period of 15 years. For "profitability" in the general case, the minimal SIR threshold is 1.0; the maximal payback period threshold is the economic life of the analysis (see Table C, Appendix E).

3. The discounted payback period may be entered as Item 23 on the Format A-1 (Appendix D).

4. Under appropriate circumstances, SIR's and discounted payback periods can be used to rank-order a set of Type I projects by economic attractiveness, as well as make the individual project determinations.

F. UNEQUAL ECONOMIC LIVES; UNIFORM ANNUAL COST

The analyses of Examples III-6 and III-7 (Subsections III-D and III-E, respectively) both compared alternatives having equal economic

lives. Indeed, the savings/investment ratio as defined above may be computed only for equal-life situations.

As previously noted, however, the majority of economic analyses are not cost reduction proposals with SIR's. They are analyses addressed to new or changed requirements and, in cases where alternatives offer comparable benefits, that alternative having the least NPV cost should be selected.

Unfortunately for the analyst, alternatives cannot always be expected to yield the same level of benefits. Although a comprehensive discussion of benefits is deferred until Section V, one unequal benefits case is of particular interest here -- that in which alternatives extend over unequal economic lives. (Just why this is a situation of unequal benefits will be illustrated shortly.)

This subsection develops a cost-oriented approach to evaluating alternatives with unequal economic lives, namely the technique of equivalent uniform annual cost prescribed in DODINST 7041.3. For the remainder of this discussion we relax the two conditions set in Subsection III-D. Instead, it will be assumed merely that alternatives addressed to the same requirement afford roughly the same level of benefits per unit time (i.e., per year). This general assumption may be valid even for situations of equal economic life; however, it will be seen to be important to the notion of equivalent uniform annual cost.

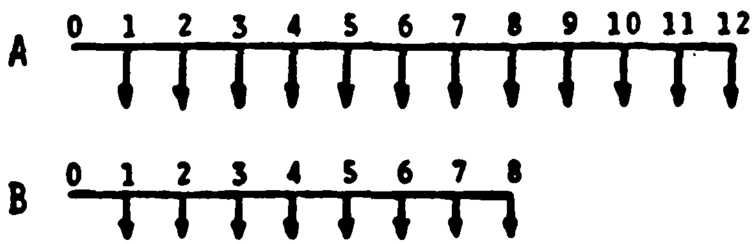


FIGURE III-10

To motivate the rationale underlying the uniform annual cost technique, consider the cash flow diagrams shown in Figure III-10. The following assumptions apply:

1. The cash flow diagrams represent alternatives addressed to the same (new or changed) requirement.

2. No end is foreseen to the requirement (mission life), nor do technological considerations play any significant role. It is therefore the limitation of physical life which constrains the economic lives of Alternatives A and B to 12 and 8 years, respectively.

3. The only costs associated with each alternative are the uniform recurring costs shown in Figure III-10.

4. The two alternatives provide an equivalent level of benefits (i.e., requirement satisfaction) per year. Thus, even if these benefits are difficult to quantify, it is clear in view of the unequal economic lives that the total benefits afforded by Alternatives A and B are not the same.

5. The annual cost of Alternative A exceeds that of Alternative B (as suggested by the cash flow diagrams).

Which alternative is preferable? Alternative B costs less per year, but Alternative A provides benefits over a longer period of time, and the requirement is open-ended.

Actually, the choice is quite easy if we make one additional assumption:

6. Each alternative may be repeated indefinitely, with the same cash flow pattern.

If Assumption 6 is valid, we may reinstitute Alternative A once and Alternative B twice, arriving at the situation depicted in Figure III-11.

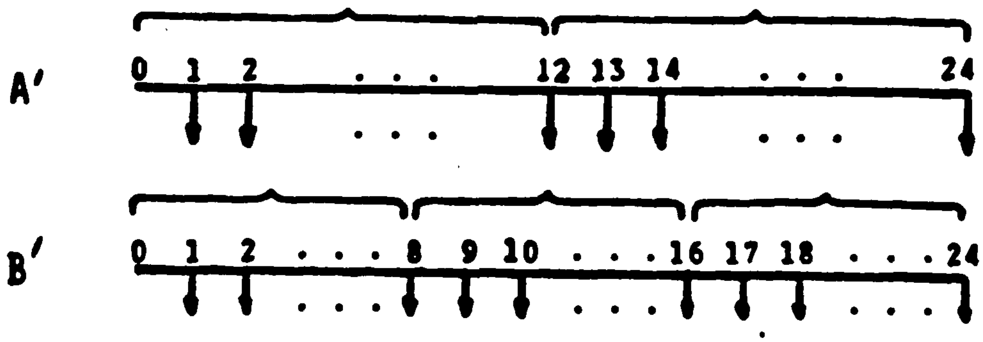


FIGURE III-11

This strategy extends both alternatives to a common point in time (the 24th year). Then, because of the general assumption that the alternatives yield comparable benefits per year, the extended Alternatives A' and B' provided equivalent levels of total benefits over the common 24 year period. We have thus transformed the unequal economic life situation of Figure III-10 into the equivalent benefit situation of

Figure III-11. To determine a preference in the latter case it is sufficient to identify that alternative having the lesser total NPV cost. In Figure III-11, it is obvious even without discounting that Alternative B' costs less -- it requires a smaller expenditure in each of the 24 years. On this basis, subject to Assumptions 1-6 above, Alternative B is to be preferred in Figure III-10. (It should be pointed out that there is nothing sacred about the periods 12 and 8 years in Figure III-10. If, for example, the economic life of Alternative B was 9 years instead of 8, two repetitions of A and three of B would extend each alternative to a common 36 year point, and the same rationale would apply.)

Of course, the absolutely uniform recurring costs in Figure III-10 made the choice easy. In reality, one could scarcely expect cash flow patterns to be so simplistic. More likely, there would be a substantial investment cost, and perhaps other one-time costs as well (possibly including terminal value). Certainly, there is no guarantee that the annual recurring costs would be uniform. Also, the least common multiple of the economic lives may be inconveniently large.

A general unequal economic life situation might resemble that of Figure III-12. Here the better economic choice is not obvious even if the costs and economic lives are explicitly known.

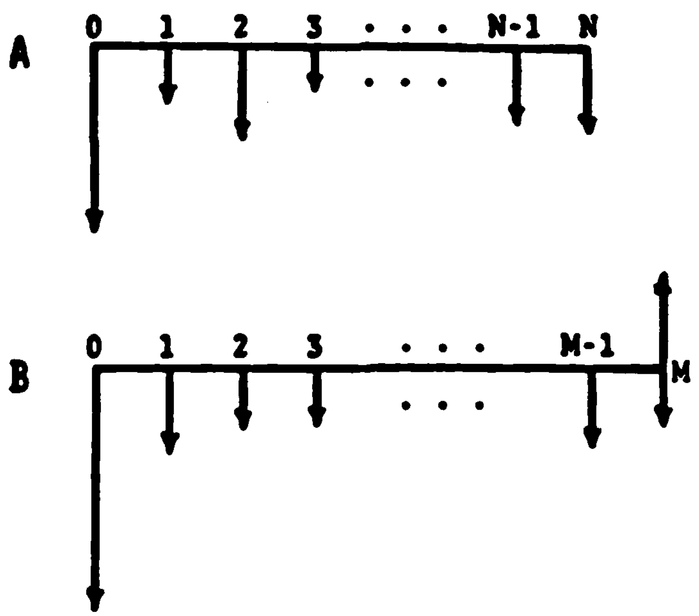


FIGURE III-12

The technique of equivalent uniform annual cost consists of converting each alternative into an equivalent hypothetical alternative

having uniform recurring costs such as those in Figure III-10. The conversion is such that the total NPV costs of the actual alternative and its hypothetical equivalent are the same (this is what is meant by the term "equivalent"). The hypothetical alternatives may then be compared on the same basis as those in Figure III-10. Once the preferred hypothetical alternative is determined, the corresponding actual alternative becomes the economic choice for the project.

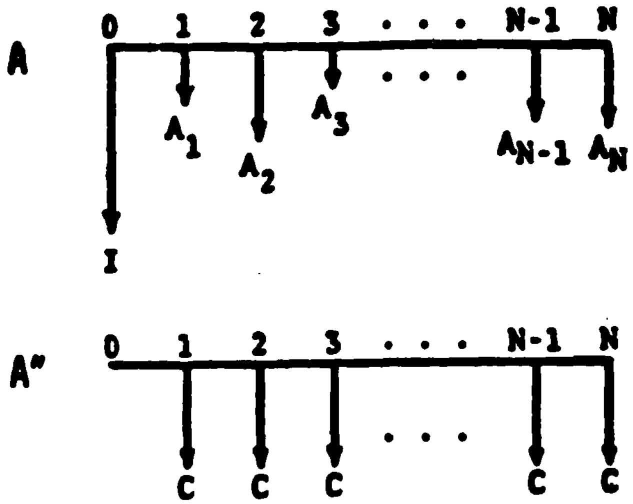


FIGURE III-13

The analytical mechanism for converting an actual alternative into its hypothetical recurring cost equivalent is just an inversion of Rule 1 (Subsection III-D). Consider Figure III-13, in which A is the first of the two (actual) alternatives shown in Figure III-10, and A" represents its hypothetical counterpart. The constant cost C in the second diagram is referred to as the equivalent uniform annual cost of Alternative A. Equating the total NPV costs of A and A", we have

$$NPV_A = C \cdot b_N, \qquad \ldots \text{(III-7)}$$

where

NPV_A = total NPV cost of A, the actual alternative (known, since the costs I, A_1, A_2, ..., A_N are assumed to be known);

b_N = Nth year Table B factor.

Solving equation (III-7) for the unknown uniform annual cost C yields

$$C = \frac{NPV_A}{b_N} \qquad \text{. . . (III-8)}$$

The technique of equivalent uniform annual cost is really nothing more than a very special case of unit costing. If, for example, a customer in a drug store were pondering whether to buy a 7 oz. bottle of shampoo for $.91 or an 11 oz. bottle (same brand) for $1.46, the rational economic choice would be dictated by comparing the two purchases on a cost per ounce basis. (Here, the 7 oz. bottle is a better bargain.) Uniform annual cost is exactly the same type of approach, except that the unit being priced is the benefit afforded by an alternative during a year's time.

EXAMPLE III-9 (OPERATION SECONDARY, CONT.): In Example III-6, Alternatives A and B were found to have total NPV costs of $141.3K and $135.8K, respectively, over their common 20 year economic life. Suppose that these alternatives are MILCON vs. rehabilitation of an existing building. Considering the 15 year lease alternative diagrammed in Figure III-14 as a third option, decide on the basis of equivalent uniform annual cost which of the three alternatives should be selected.

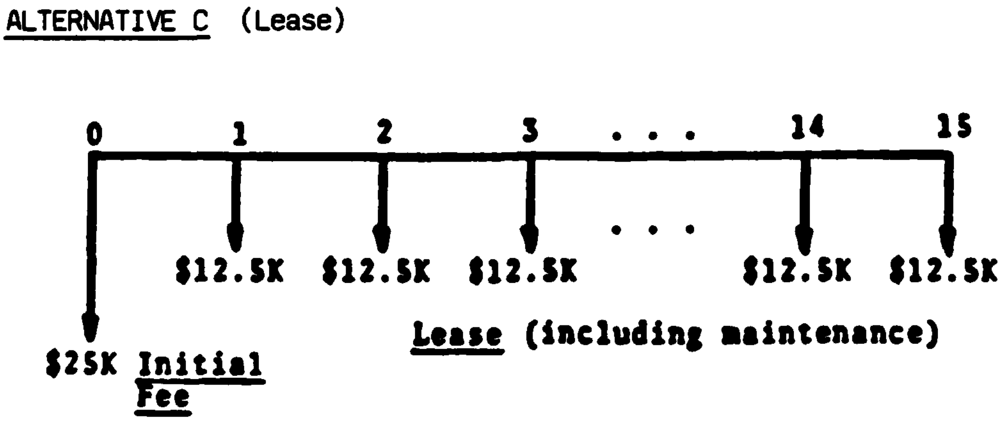


FIGURE III-14

SOLUTION: First, it is necessary to compute the total NPV cost of Alternative C. The calculations are displayed in tabular form below:

Project Year(s)	Cost Element	Amount One-time	Amount Recurring	Discount Factor	Discounted Cost
0	Initial Fee	$25K		1.000	$25.0K
1-15	Lease		$12.5K	7.980	$99.8K

TOTAL NPV COST: $124.8K

The uniform annual cost computations for the three alternatives are as follows:

ALTERNATIVE A: $\frac{NPV_A}{b_{20}} = \frac{\$143.1K}{8.933} = \$15.8K$

ALTERNATIVE B: $\frac{NPV_B}{b_{20}} = \frac{\$135.8K}{8.933} = \$15.2K$

ALTERNATIVE C: $\frac{NPV_C}{b_{15}} = \frac{\$124.8K}{7.980} = \$15.6K$

REMARKS:

1. In accordance with equation (III-8), each total NPV cost is divided by the Table B factor corresponding to that alternative's economic life.

2. The significance of the $15.8K uniform annual cost for Alternative A is this: If $15.8K were to be spent each year for 20 years, the total net present value of the payments would be $143.1K, the same as the actual NPV cost of the alternative. Analogous comments apply for Alternatives B and C.

3. Since Alternative B has the least equivalent uniform annual cost, it is the one to be recommended on economic grounds.

4. In Example III-6, B was found to be a cheaper alternative than A. The calculations above show that it also has a lower equivalent uniform annual cost. This should come as no surprise, because the two

total NPV costs are divided by the same (20 year) Table B factor, thus preserving the inequality. In fact, a uniform annual cost comparison of alternatives having the same economic life always produces the same preference ranking as a simple NPV comparison. The point is that uniform annual cost is a useful tool only in cases of unequal economic lives. If all alternatives have the same economic life, computation of equivalent uniform annual costs is a superfluous exercise which, although not incorrect, generates no new useful information.

The technique of uniform annual cost should "spread" cash flows over the actual economic life only, and not over any period of lead time, even if costs are actually incurred during such a period. (This is consistent with interpreting uniform annual cost as the average yearly cost of securing benefits. The uniform annual cost extends only over the period during which benefits actually accrue to the Government.) Consider the following example.

EXAMPLE III-10: Perform an equivalent uniform annual cost comparison of the two alternatives represented by the cash flow diagrams of Figure III-15.

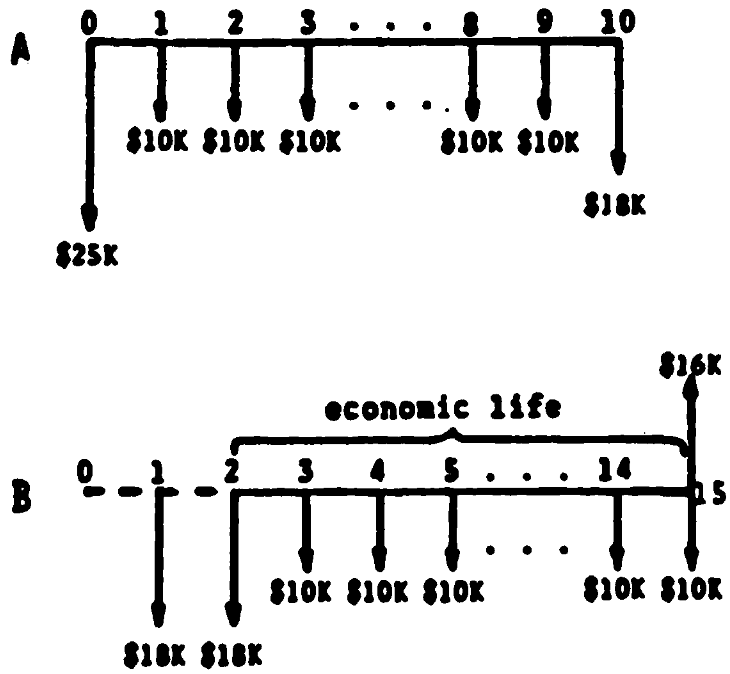


FIGURE III-15

DISCUSSION. Alternative A, which starts offering benefits immediately, has an investment cost of $25,000 and an annual cost of $10,000. The extra one-time cost of $8,000 in the 10th year might be, say, for demolition, dismantling and removal of an asset, or restoration of a site to its original condition (as part of a contractual agreement).

Alternative B has a total investment cost of $36,000 spread uniformly over a two year lead time. The alternative does not become operational until the beginning of Year 3, at which point its economic life starts. (The lead time period is dashed in the cash flow diagram to indicate that it is not part of the economic life. The total 15 year period shown is referred to as the project life of the alternative.) This alternative, too, requires an annual expenditure of $10,000. Residual (terminal) value of the asset is $16,000.

SOLUTION:

ALTERNATIVE A

Project Year(s)	Cost Element	Amount		Discount Factor	Discounted Cost
		One-Time	Recurring		
0	Investment	$25K		1.000	$25.0K
1-10	O & M		$10K	6.447	$64.5K
10	Restoration	$ 8K		0.405	$ 3.2K

TOTAL NPV COST: $92.7K

$$\text{EQUIVALENT UNIFORM ANNUAL COST} = \frac{\$92.7K}{6.447} = 14.4K$$

ALTERNATIVE B

Project Year(s)	Cost Element	Amount One-Time	Amount Recurring	Discount Factor	Discounted Cost
1-2	Investment		18K	1.821	$32.8K
3-15	O&M		10K	7.980 -1.821 6.159	$61.6K
15	Terminal Value	($16K)		0.251	($ 4.0K)

TOTAL NPV COST: $90.4K

$$\text{EQUIVALENT UNIFORM ANNUAL COST} = \frac{\$90.4K}{7.980 - 1.821} = \frac{\$90.4K}{6.159}$$

REMARKS:

1. The economic life of Alternative B extends over a 13 year period (from the beginning of Year 3 through the end of Year 15). The equivalent uniform annual cost, $14,700, is that amount which, if paid annually from Year 3 through Year 15, would total $90,400 in Time Zero dollars, the same as the total NPV cost of the actual alternative.

2. Alternative A is economically preferable as it has the lower equivalent uniform annual cost.

3. A generalization of the approach used in this example would be the following: If an alternative has a project life of N years, of which the first M years is lead time (and therefore not part of the economic life), its equivalent uniform annual cost C is given by

$$C = \frac{NPV}{b_N - b_M} \qquad \text{. . .(III-8a)}$$

where NPV represents the total net present value cost of the alternative.

4. Had we made the mistake of dividing $90,400 by 7.980 (the 15 year Table B factor) in the uniform annual cost computation for Alternative B, we would have obtained $11,300, thereby concluding erroneously that this alternative was preferable.

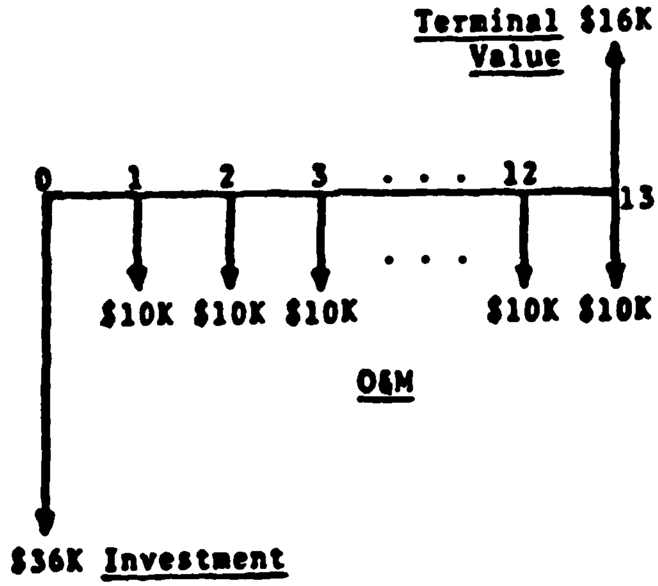


FIGURE III-16

5. Suppose Alternative B had been obtainable with the same economic life and for the same costs, but without the two year lead time. I.e., suppose it were represented by the cash flow diagram in Figure III-16. The reader may verify for himself that the total NPV cost would be $105.6K, and the equivalent uniform annual cost, $14.2K. (Under these circumstances Alternative B would in fact have been preferable to Alternative A.) The equivalent uniform annual cost for the actual Alternative B of Example III-10 is $14.7K. Thus, the necessity to spread the investment cost over a two year lead time serves to penalize Alternative B in the uniform annual cost comparison. This would seem appropriate, because the lead time amounts to an extra two year delay in the satisfaction of a deficiency. (The problem of differing lead times is a general one which can occur in equal-life situations as well. In those cases, for purposes of the present value calculations, the DODINST 7041.3 recommends aligning the economic lives by taking the economic life of each alternative as beginning in the same base year. This imposes a penalty on those alternatives having longer lead times.)

To summarize the key ideas in this subsection, uniform annual cost is an economic analysis technique used to compare two or more alternatives having different lives. The technique is theoretically applied in two stages:

1. Each alternative is transformed into an equivalent hypothetical alternative having uniform recurring annual costs and the same total NPV cost as the actual alternative.

2. The hypothetical alternatives are the compared according to the rationale accompanying Figures III-10 and III-11.

In actual practice, it is customary to determine equivalent uniform annual costs directly from equation (III-8) or (III-8a) without explicitly constructing the hypothetical alternatives. (This is what was done in Examples III-9 and III-10.) That alternative having the least equivalent uniform annual cost should be the one selected.

NOTE: Uniform annual cost is not the only technique for deciding between alternatives with different economic lives. Another procedure, cited in DODINST 7041.3, is "to base the time period of the analysis on the economic life of the asset (alternative) with the shorter time period. In this case the residual value of the asset with the longer economic life must be considered in the computation of the costs of that alternative." The drawback to this approach is that it does not employ all the cost informaton available for the second alternative (specifically the costs occurring in the out-years beyond the end of the shorter economic life), and it leads to typical difficulties in the assessment of terminal value. (See Section IV.) Yet another procedure is to assume a follow-on action, with attendant costs, that will extend the shorter-life alternative to a project life equal to that of the other alternative.

IV. COST ANALYSIS

A. GENERAL COMMENTS

Cost refers to the value of inputs such as materials, operating labor, maintenance, supplies, and capital expended in producing a good or service. To be realistic, cost estimates must refer to all ramifications of alternatives being analyzed. Well-performed cost analysis of an operation requires detailed investigation into where money comes from, where it goes and what it buys.

Throughout this handbook, the process of economic analysis is described in various ways--a formalization of common sense, a systematic approach to evaluating problems of choice, etc. Central to all these alternative definitions is the notion that economic analysis is a system which operates on certain input data and provides an output--a measure of project cost effectiveness--to aid the decision-maker. The best and most complete of systems can yield output only as good as the input data supplied, and economic analysis is no exception to this rule. Solid, well-documented cost input data provide the foundation for the analysis and are absolutely essential to it. Nothing improves the output of an economic analysis more than good input; meaningful conclusions can be drawn only from meaningful cost data.

B. LIFE CYCLE COSTING

Economic analysis provides a tool for effective resource allocation only when all the resource implications associated with each alternative--whether they be direct or indirect--are included. Therefore, life cycle costing must be employed. Life cycle cost in an economic analysis is the total cost to the Government of acquisition and ownership of an alternative over its full life. It includes the costs of development, production, operation, support and, where applicable, disposal. (As emphasized in Section III, the timing of these costs is important to consideration of opportunity cost through present value techniques as well as to budgetary considerations.)

A Navy decision to undertake an investment implies the allocation of many different resources and the tapping of several different "pots" of money. The construction of a Public Works Maintenance Shop, for example, involves not only the construction investment cost, but also the allocation of Navy land resources, the commitment of Navy funds for personnel, operations, routine maintenance, and other recurring expenditures throughout the facility's economic life, and other resource allocations as well. Any attempt to evaluate an investment option without due consideration of all the resource implications is incomplete.

The ultimate purpose of an economic analysis is to provide one piece of data which the decision-maker will use in the Navy resource

allocation process. Specifically, the economic analysis should present an unbiased picture of the full life cycle resource/benefit implications of each alternative considered. Only when the decision-maker has such an unbiased presentation is it possible to achieve the highest level of national defense possible within the constraints of the Navy budget.

C. POINT OF VIEW

When compiling life cycle costs, the analyst must take the appropriate vantage point to ensure that all relevant costs are included. The correct vantage point is that of the United States Government. This posture not only provides for the maximum effectiveness of national defense resource allocation but is also appropriate in that the highest level of approval sought for a resource allocation decision is that of Congress and the President. The Congress naturally is interested when a program or project of one Federal agency has impacts on the costs incurred by another Federal agency.

An example of a case in which costs to a Naval activity may differ from costs to the Federal government as a whole is that in which the Naval activity occupies a building which is leased from a private owner through the General Services Administration (GSA). GSA levies a charge on the Naval activity called the Standard Level User Charge (SLUC). The SLUC, however, does not necessarily represent the cost to GSA to provide the building. Thus, if an alternative is considered in which there will no longer be a requirement for the leased building, the savings to the Government are not the amount of the SLUC payments which the Naval activity no longer has to pay, but rather the actual costs which GSA had been paying for rent, utilities, maintenance, etc. (In some cases, the analyst may wish to prepare a second comparison of alternatives which shows only the costs to the Navy. Such a comparison, however, is to be considered supplemental information to an economic analysis only, and not a substitute for an economic analysis.)

D. SUNK COSTS

The principle of full life cycle analysis applies to all costs and benefits which occur after the decision point (i.e., the time at which the economic analysis is prepared.) The economic analysis includes only those cash flows which the decision can affect. Costs which occur prior to the decision are sunk and cannot be altered or recaptured. For example, if an alternative is linked to a research effort undertaken prior to the decision point involving past expenditures of $300,000, the research cost must be disregarded when estimating the cost of the alternative. The $300,000 is a sunk cost and cannot be affected in any way by the choice among alternatives. Sunk costs are never included in the economic analysis, although their mention as supplemental information may be of interest to budget reviewers.

E. COST ELEMENTS

The following is a representative list of cost elements to be included for each alternative considered in an economic analysis. The list is intentionally broad and it is unlikely that any one analysis will include all the cost elements described below. The analyst should consider it a checklist against which each alternative should be measured. (Conversely, the list may not be broad enough to meet the requirements of certain analyses, and the analyst should augment the list as necessary.)

1. ONE-TIME COSTS.

a. Research and Development (R&D) - all costs for research and development incurred after the decision point (i.e., no sunk costs included.) Each cost should be identified by year.

b. Facility Investment Costs - costs associated with the acquisition of equipment, real property, nonrecurring services, nonrecurring operations and maintenance (startup) costs, and other one-time investment costs. Investment costs may be spread over several years, and the year(s) must be identified. These costs include:

1) land acquisition or easements

2) new construction

3) rehabilitation or modification

4) collateral equipment

5) plant rearrangement and tooling

6) demolition and site restoration

7) one-time personnel costs (recruitment separation, training, etc.)

8) relocation costs

9) nonrecurring services

c. Working Capital Changes (plus or minus) - money tied up in liquid funds, or assets on hand or on order. Generally, working capital is some form of inventory of consumables or similar resources held in readiness for use or in stock. Working capital changes can be positive (representing additional funding requirements) or negative (representing a reduction in funding requirements.) Negative change figures should be enclosed by parentheses ( ) so that the reduction in funds will be subtracted from other investment costs for the alternative. Most military construction projects will have little or no effect on working

capital, but for purposes of illustration some examples of working capital changes effected as a result of new construction are:

1) conversion of utility plants from coal or fuel oil to commercial natural gas may allow a reduction in fuel stocks (minus);

2) construction of modernized repair shop facilities with new production equipment will increase the capacity of the shop, reducing "pipeline" stocks of end items necessary to be maintained in the "under repair" status (minus);

3) construction of a supplemental Navy Exchange gasoline filling station, due to overcrowding and congestion at the existing service station, will require increased capital invest ment to stock additional gasoline in new storage tanks (plus).

d. Value of Existing Assets Employed (plus) - the value of assets already on hand which are to be used with the new project. However, the value of such existing assets shall be included in the investment costs only when one of the two following conditions is met:

1) when the use of the existing asset will result in a cash outlay on some other project which would otherwise not be incurred; i.e., when the existing asset is currently in use (or has an alternative planned use) on some other project

or

2) when the use of the existing asset will deprive the Government of cash planned to be realized by sale.

In all other cases, the value of existing assets employed will be treated as sunk cost.

When the value of existing assets employed is included, the existing assets should be included at their fair market value (as measured by market price, scrap value, or alternative use value) and the basis for arriving at the estimate shall be fully documented.

e. Value of Existing Assets Replaced (minus) - the value of assets or property already on hand, the current need for which is eliminated by a proposed project. If this property is then sold, the proceeds benefit the Government; they are included in Miscellaneous Receipts by the U. S. Treasury Department. If the property is redistributed to some other federal or state agency, that agency is benefited even though there is never any reimbursement or cash flow to

the Navy or other agency which controlled the property initially. The fair market value of these replaced assets (as measured by sale price, scrap value, or alternative use value) should be treated as a reduction in the investment required by the U. S. Government for decision-making in the economic analysis if (and only if) there is a documented alternative use for the assets.

NOTE: Documentation of alternative use is necessary to both value of existing assets employed and replaced. When no documentation is possible, the analyst (and the reviewer) should assume the assets to be of no value and therefore irrelevant to the economic analysis.

f. Terminal Value - an estimate of the value of the proposed investment at the end of its economic life. Future terminal value is impacted by such factors as the probability of continued need for the asset (for Government or private use), appreciation, and depreciation (physical and functional). The effect of these factors upon future terminal value normally cannot be estimated with any measurable dgree of certainty. Moreover, any salvage value realized may be almost or completely offset by removal, dismantling, or disposal costs.

Further, the impact of the present value of the future terminal value of a given alternative is likely to be insignificant. For example, for an economic life of 25 years, the present value of terminal value is only 9.7% of the estimated value at that time (since the 25th year Table A discount factor is 0.097). The terminal value should be included in the analysis, accompanied by a documented rationale for the estimate. Particularly noted should be any assumptions regarding probable need for the facility beyond the evaluation period.

Assessing the terminal value accurately is a difficult process since the effects of depreciation and appreciation must be considered simultaneously. Specifically, this raises the question of how to treat inflation, which is covered fully in Section VII (and briefly in Subsection IV-G).

NOTE: Net total investment is the algebraic sum (plus and minus) of the dollar amounts of the one-time cost elements a, b, c, d, e and f above. In the event these investment costs do not occur during the project base year (Time Zero), all costs shown must be converted to their equivalent present value costs for the project base year.

2. RECURRING ANNUAL COSTS.

a. Personnel Costs - all costs of civilian and military personnel and employee benefits.

1) Civilian. The method to be used for calculation of personnel costs depends upon whether the requirements are

expressed in numbers of people or in man-hours of work. In either case the base pay for civilian personnel services involved directly in the work to be performed is computed based upon current General Scheduale (GS) or Wage Board (WB) pay tables, which are available at the appropriate personnel office. (Step 5 is used as a representative average within a GS grade level; step 3 is used as a representative average within a WB grade level.) Methods for the two cases are:

a) Number of personnel - when the civilian personnel services are specified in terms of the number of personnel required, the base pay should be accelerated by a figure to account for the Government's contribution for civilian retirement, disability, health and life insurance, and, where applicable, social security programs. The appropriate acceleration rates at the time of publication of this handbook, as established by the Office of Management and Budget are:

* Retirement and Disability (for employees under Civil Service Retirement)	20.4%
* Health and Life Insurance	3.7%
* Other Benefits (including work disability, unemployment programs, bonuses and awards, etc.)	1.9%
TOTAL	26.0%

Thus, for employees under the Civil Service retirement system, base pay should be accelerated by 26% to account for Government furnished fringe benefits.

b) Man-years of work - when civilian personnel requirements are specified in terms of the number of man-years of work required, the base pay must be accelerated both for Government furnished fringe benefits (usually 26% as above) and for formal training, annual leave, sick leave, and other classifiable absences. This is necessary since, due to such absences, more than one person is required to perform one man-year of work. (One man-year is defined as 2080 hours, or 260 days of 8 hours each, or 52 weeks of 40 hours each, of work.) The usual acceleration rate in the Continental U.S. CONUS for leave and other absences is 20%, which figure should be used when local data is not obtainable from the activity comptroller.

The net acceleration rate is approximately 51%, since fringe benefits are accrued by an employee both

when on leave and when at work. For example, to accomplish X man-years of work per year, a civilian on board strength of 1.2X would actually be required. Due to the cost of fringe benefits, each of these 1.2X people costs the Government 126% of the annual salary each year. Therefore, the total annual personnel cost of X man-years of work is approximately $(1.2X)\cdot(1.26) = 1.51X$ times the annual salary.

2) Military. Complete military personnel costs forservices involved directly in the work performed, computed as described in NAVCOMPT Manual 035750. The standard work period for computing military personnel costs is also based on an established 40 hour work week, 52 weeks/year, 260 days/year or 2080 hours/year. Composite standard military rates prescribed in Appendix C of NAVCOMPT Manual 035750 should be used for estimating costs of military personnel services. These rates should be accelerated for military retirement, other personnel costs and leave by using the rates in the manual.

3) Other. Personnel costs (itemized) not included under the first two items above, such as travel, per diem, moving expenses, training, etc.

b. Operating Costs - all operating costs (other than labor). Each major subcategory should be itemized.

1) Materials, Supplies, Utilities, and Other Services. The cost to the Government of supplies and materials used in providing a product or service. Included in this figure are the cost of base transportation which can be directly identified with the function, costs for handling, storage, custody and protection of property, and the cost of utility services, including electric power, gas, water, and communications related to the function. Cost of material and supplies should include consideration for reasonable overruns, spoilage or defective work.

2) Maintenance and Repair. The cost of maintenance and repair to buildings, structures, grounds and equipment utilized by the function involved in producing goods or services. (Capital improvements, however, should be included with one-time investment costs rather than here.)

3) Support Costs (Including Overhead). The costs of accounting, legal, local procurement, medical services, receipt, storage and issue of supplies, police, fire and other services; also the costs of terminating or cancelling any existing arrangements which will become due as a result of implementing an alternative in question. When estimating support costs associated with an alternative, care must be

taken to itemize only those support costs which will change as a result of the investment proposal. For example, construction of a new UEPH will probably not affect the size of the base fire department, but the costs of operating the fire department may be included in the general base overhead. Thus, only the variable components (with respect to the alternative under consideration) and not the fixed components of support cost should be included. (When a change in cost is due to a change of a single unit of output, it is referred to as marginal cost.)

c. Other - any other recurring annual costs which do not fit easily into the categories mentioned above. All such costs should be itemized.

F. DEPRECIATION

When considering the recurring annual costs associated with a given investment alternative, the analyst may ask the question, "What do I do about the fact that this facility is going to wear out?", or stated another way, "How do I include an allowance for depreciation?" The answer is that he does nothing at all since generally depreciation has no effect on cash flow for Government investments. The appropriate cost to be charged annually to an investment alternative is the cost of using it during the year. This user cost is precisely what was defined previously under Recurring Annual Costs.

In the private sector, the depreciation writeoff of a long-term asset is an accounting expense which neither requires nor generates cash and therefore has no effect on the firm's cash balance before taxes. However, due to the nature of U. S. tax laws, a firm can deduct its depreciation allowance from net income before paying taxes, thus reducing its tax bill.

In summary, depreciation writeoff is an accounting convention which impacts on cash flow only when an income tax structure exists. Since the Government pays no taxes, depreciation expense is irrelevant and should not be included in an economic analysis of Government investments. The concept of depreciation is used by the analyst only when attempting to estimate the terminal value of an asset.

G. INFLATION

The effects of inflation during the planning period covered by an economic analysis may impact on the decision-maker's preference for one alternative over the others under consideration. When this is the case, the economic analysis should include an explicit treatment of inflation.

It is useful at this point to define two terms related to the measurement of costs:

Constant dollars - Dollars of constant purchasing power. Constant dollars are always associated with a base year (e.g., Fiscal Year 1984 constant dollars). An estimate is said to be in constant dollars if all costs are adjusted so that they reflect the level of prices of the base year.

Current dollars - Dollars that are current to the year of their expenditure. When past costs are stated in current dollars, the figures given are the actual amounts paid out. When future costs are stated in current dollars, the figures given are the amounts which will be paid including any amount due to projected future price changes.

Economic analysis requires measuring the value of costs and benefits. The unit of measure used is the dollar. To avoid distortions due to changes in the value of the unit of measure when the general price level changes, all estimates of costs and financial benefits should be made initially in terms of constant dollars, that is, in terms of the general purchasing power of the dollar as of the analysis base year (Year 0). In this baseline analysis, projected annual costs should vary only to the extent that the required level of procured goods and services is expected to vary during the project life. For example, it would be legitimate for annual costs to reflect an increase in the anticipated amount of repairs needed, as measured by prices in effect at the beginning of the project life, since this represents a real cost increase and not an inflationary one. (Because constant dollar estimates are used in economic analyses, the numbers given generally are not budget estimates, which should reflect anticipated inflation. However, economic analyses are often useful in the preparation of budget submissions.)

As explained in Section VII, application of standard 10% discount factors (from Tables A and B, Appendix E) to constant dollar costs actually adjusts for the general inflation rate during the project life due to the manner in which the 10% rate was derived. However, if one or more cost elements are expected to undergo abnormal escalation in the long term, and such sustained anomalous escalation is potentially important to the conclusion of the analysis, then it should be explicitly addressed. Because of the great uncertainties involved, inflation is best treated by sensitivity testing. The general subject of sensitivity analysis is developed in Section VI; for specific examples of cost escalation uncertainty tests, refer to Subsection VII-D.

H. COST-ESTIMATING METHODS

This section has stressed the principle of full life cycle costing and developed a representative checklist of cost elements to be considered in such a procedure. With experience, the identification of appropriate cost elements should become a matter of routine for the economic analyst.

The actual estimation of costs, however, may be a less tractable problem. Historically, this has proven to be true in the procurement of weapon systems and in analyses of large and complex programs. In many cases, the system or program to be costed simply has not had any precedent. Under such circumstances, prior cost estimating experience may not keep the task at hand from becoming formidable.

To help meet the practical problems of cost estimation, a number of unique methodologies have been developed. In the current state of the art, some of these techniques are less often applied to the facilities area than others. However, since a treatment of cost analysis would not be complete without at least identifying the most important cost-estimating procedures, three basic approaches are briefly described below.

1. INDUSTRIAL ENGINEERING METHOD. This approach consists of a consolidation of estimates from various separate work segments into a total project estimate. For example, the estimated cost of producing a new model "widget," which will entail work contributions from 10 separate work divisions in a plant, could well be an aggregation of 10 separate and detailed estimates, each of which might itself be composed of several subestimates. A more familiar example is that of an architect estimating the cost of a new house. He may estimate the construction cost as being equal to the sum of the structural, electrical, plumbing, heating, finish and other costs. Each subestimate may have numerous labor, materials, and equipment components.

2. PARAMETRIC COST ESTIMATING. In parametric cost estimating, the total cost of an alternative is based upon ascribed physical and performance characteristics and their relationships to highly aggregated component costs. In other words, a functional relationship must be established between the total cost of an alternative and the various characteristics or parameters of the alternative. The term "parameter" is formally defined as a cost related explanatory attribute which may assume various values during actual calculations. As an example, the family contemplating the purchase of a new house might consider the following parameters (among others):

* number of bedrooms

* number of baths

* number of dens

* number of finished recreation rooms

* number of attics

* capacity of the garage

* size of the property lot

* age of the house

* location

If a house price for any particular combination of these parameters is known (say, the expected selling price of the house currently occupied by the family), then prices for other parameter mixes may be estimated relative to this baseline (perhaps, in this particular case, with the assistance of a real estate agent).

The greater the number of actual combinations for which the prices are known, the easier it is to estimate the effects of a particular parameter on the total cost. The aim of the analyst is to develop a valid Cost Estimating Relationship (CER). CERs are frequently derived through regression analysis, which relates cost as a dependent variable to physical and performance characteristics, which are independent variables.

Figure IV-1 illustrates the use of regression analysis to develop a CER for UEPH project construction cost. Historical UEPH project construction costs were escalated to 1980 constant dollars. The scattered points in Figure IV-1 show the combinations of square meters of area and construction cost in 1980 dollars. The line shown is the "best fit" of a linear relationship between area (the independent variable) and construction cost (the dependent variable). It allows the analyst to estimate the construction cost for a new UEPH project given that the gross area to be constructed is known. The distances between the line and the points give a visual impression of the statistical confidence of the estimate. (Of course, the analyst might wish to develop a CER that uses, in addition to the gross area of the project, other independent variables such as number of buildings, number of stories, capacity of air conditioning system, etc. Multiple regression analysis could be applied for this purpose.)

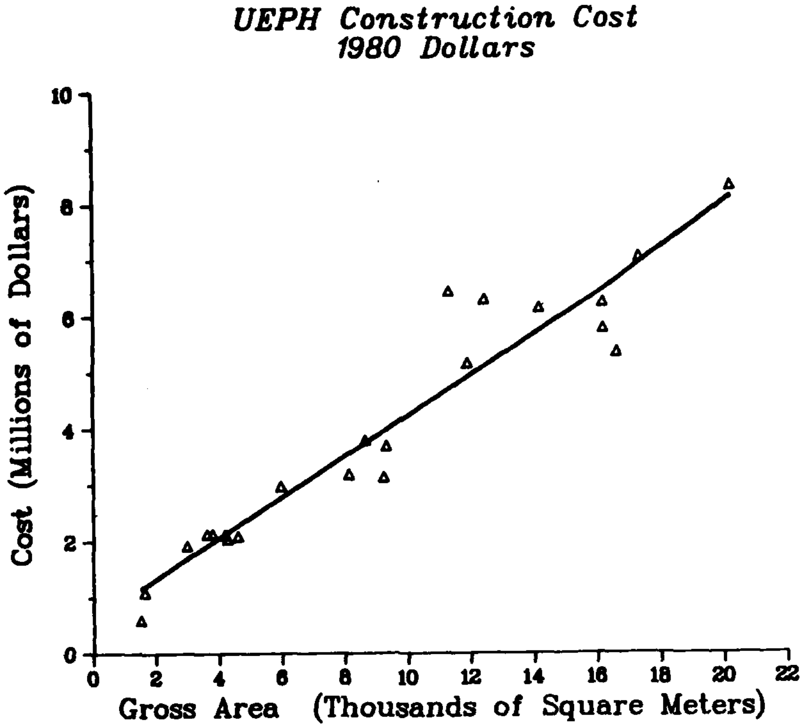


FIGURE IV-1

3. ANALOGY METHOD. *If more formal techniques cannot be* applied, a specialized method of judgment, called the analogy method, may be used to estimate costs by making direct comparisons with historical information on similar existing alternatives or their components. It is probably the most widely used method of cost anlysis to date. The major caution of the analogy method is that it is basically a judgment process and, as a consequence, requires a considerable amount of experience and expertise if it is to be done successfully. Moreover, judgment should always be recognized for what it is, namely a guess, albeit an educated guess.

Estimation of facilities acquisition costs may place heavy reliance on the analogy method. At the activity level, the process will obviously be influenced by the recent history of construction costs for that region. Even if cost estimates are available from an "expert" source such as a local architect and engineering firm, these estimates will essentially be extrapolations of the firm's recent experience in labor, materials, and overhead costs.

Those engaged in the review of cost estimates should find a useful guide in the NAVFAC P-438, Historical Military Construction Cost Engineering Data, and the NAVFAC P-448, Conceptual Military Construction Ccst Engineering Data. These sources provide, for individual category

codes, unit costs with adjustments for area, size, Supervisory Inspection and Overhead (SIOH) and contingencies, and short term cost escalation projections. Brief but specific physical descriptions of facilities are also included. Similar but more condensed guidance is provided in the Military Construction Cost Review Guide (DOD 4270.1-CG), a manual which is issued and regularly updated by the Office of the Deputy Assistant Secretary of Defense, Installations and Housing.

Estimates of facilities related recurring annual costs also lend themselves to the analogy method. Such estimates will necessarily depend heavily on expert judgment, seasoned by experience as documented in public works O&M cost records.

In summary, providing good cost data is often the most demanding and time consuming task required for the preparation of an economic analysis. Even with the application of one or more of the techniques outlined above, the results are by no means certain. Consequently, the cost estimates of an investment proposal are a major focal point of sensitivity analysis (see Section VI).

I. ACCURACY OF COST ESTIMATES

The analyst must choose the level of detail and accuracy in cost estimating, which will depend upon the purpose of the cost estimate. Detail and accuracy are generally classified into three levels:

1. Order-Of-Magnitude Estimates
2. Semi-Detailed Estimates
3. Detailed Estimates

The analyst is often confronted with a tradeoff between the accuracy of an estimate and the ease with which the estimate is made. Order-of-magnitude estimates, which are the easiest to obtain, have a very low level of accuracy; the actual cost may easily differ from an order-of-magnitude estimate by as much as 35 percent or more.

Semi-detailed estimates are generally considered to be accurate to within about 10 percent of actual cost. This level of accuracy is often adequate for some of the estimates in an economic analysis.

Detailed estimates are of the type used in making bids. These estimates should be within approximately 5 percent of actual costs, since these are prepared from complete plans and specifications. Detailed cost estimates are time consuming to prepare and all the necessary details may not be known at the time that the economic analysis is performed. However, detailed estimates should be used in economic analysis whenever it is feasible.

Whatever their accuracy and level of detail, all cost estimates should be made with care and applied with full recognition of their

limitations; the adequacy of the level of accuracy used should be verified through sensitivity analysis.

J. DOCUMENTATION

Just as important as the quality of the cost data, and an essential complement to it, is sound and defensible data documentation. The analyst should always bear in mind that his work is subject to many different levels of review in the Navy budget formulation process. The most detailed review should occur at the cognizant Engineering Field Division (EFD), but this is by no means the only one. Personnel at NAVFAC Headquarters, on Major Claimant staffs, in the offices of both the Navy Comptroller and the Secretary of Defense, and at the Shore Facilities Programming Board review the analyses with appropriate scrutiny. Finally, when a MILCON project is reviewed by Congressional committees for inclusion in the budget, everything about it is subject to detailed inquiry, including the economic analysis and its cost data. The analysis may be reviewed by the committee staff or by General Accounting Office (GAO) auditors. None of these budget reviewers is as familiar with the economic analysis as is the actual analyst himself, and yet each of them must review the analysis critically and pass judgment upon its validity and adequacy. This state of affairs demands that the analyst provide complete documentation for his work.

The economic analysis should be complete in itself--the reader should not have to search other documents for information necessary for comprehension and support of the analysis. For each cost element included in the analysis, the documentation should address at a minimum the following points:

* specific data source
* method of data derivation, if applicable
* an assessment of the accuracy of the cost estimate

This requirement is nothing more than what is dictated by common sense and good professional practice, and the analyst should exercise prudent judgment in determining the appropriate level of documentation necessary. In making this determination the following general suggestions are offered:

1. Identify the dominant cost elements. These are costs whose present value equivalents have a significant impact on the total present value cost of the alternative under investigation. In other words, these are the driving factors of the total present value cost. Accordingly, dominant cost factors should be supported with detailed documentation.

2. Identify any cost factors which are sensitive, politically or otherwise. Such costs are subject to more careful review than might otherwise be required, and thus demand complete documentation. (This guideline applies to "sensitive" assumptions inherent in the analysis as well.)

3. Provide documentation for all other cost data proportional to their impact on the analysis.

When providing cost data documentation the analyst should bear in mind the ultimate purpose for which the analysis is intended--to help the decision-maker determine the most cost effective allocation of Navy resources. Further, he should remember that the economic analysis is one of the pieces of information used to support the MILCON program before Congress. Both of these goals will better be served if the documentation guidelines suggested above are followed.

V. BENEFIT ANALYSIS

A. INTRODUCTION

The essential aspects of an economic analysis are the identification of all the relevant inputs and outputs and the quantification of these as costs and benefits to facilitate evaluation. Any economic analysis will involve considerations of both costs and returns expected for each alternative. For purposes of this handbook, the term "benefits" is used as the overall term for returns (outputs, products or yields). The benefits of each alternative should be expressed so that the decision-maker is able to compare various alternatives. This is usually done by the benefit/cost ratio (BCR). The benefit/cost ratio is defined in most general terms as benefits divided by costs or:

$$BCR = \frac{\text{Benefits}}{\text{Costs}} \qquad \ldots \text{(V-1)}$$

for each alternative considered.

Thus far, this handbook has considered only the very special but frequently occurring case in which the benefits associated with all alternatives are roughly comparable, and the comparison of costs and benefits correctly focuses only on the costs. However, there are many instances in which the assumption of equivalent benefits is a poor one. Additionally, it is advisable to describe a project in terms of a quantifiable output measure when possible. This is the subject of benefit analysis.

The perceptive reader will note that one example of direct comparison of costs and benefits has been treated already. This is the savings/investment ratio (SIR) developed for use in a Type I economic analysis for projects justified on the basis of projected cost savings relative to the status quo (see Subsection III-E). In other words, a Type I economic analysis applies to a project whose measurable benefits include literal recurring cost savings, relative to the current situation, which have a total life cycle present value in excess of the project investment cost.

Most Navy investments do not fit nicely into the domain of Type I economic analysis, but this is to be expected. After all, the Navy is not in the business of making money, but rather in the business of providing national defense. Consequently, the benefits of Navy investments are more likely to be stated in other terms. These benefits are just as important as cost savings, however, and deserve to be brought to the decision-maker's attention. The economic analysis is the logical vehicle for presentation of this benefit/cost information.

B. COMPARATIVE CONFIGURATIONS

There are, in general, four possible configurations of costs and benefits for alternatives under investigation:

1. EQUAL COSTS/EQUAL BENEFITS. This most simple case occurs very infrequently and has a trivial solution. When both present value costs and benefits of all alternatives are equal, the economic analysis indicates no financial preference, leaving the decision-maker free to choose his course of action on the basis of other good management criteria.

2. UNEQUAL COSTS/EQUAL BENEFITS. Most analysts should be very familiar with this configuration, as it is the one most frequently employed for analyses in support of the MILCON program. Again, the solution is straightforward, since the assumption of equivalent benefits for all alternatives permits the analyst to focus on only the cost side of the benefit/cost equation. From a financial viewpoint, that alternative having the lowest total net present value of costs is preferable.

3. EQUAL COSTS/UNEQUAL BENEFITS. Although very rarely encountered, this configuration allows the same type of straightforward solution. Under the assumption of equal costs, the analyst need consider only the benefits of each alternative. All other things being equal, that alternative with the highest level of total present value benefits is selected. Implicit in this comparison is the ability to state definitively what the relevant benefits are, and to rank them in some meaningful way.

4. UNEQUAL COSTS/UNEQUAL BENEFITS. The final configuration is the most complex to analyze in that it may require a discounted (present value) analysis of both benefits and costs. Further, it requires some method of comparing these benefit and cost streams for each alternative. Despite its complexity, the unequal costs/unequal benefits case is the most interesting and useful case for investigation. It is the most general case, and a full understanding of its nature provides an excellent foundation for the analysis of other, more simple cases.

C. BENEFIT ANALYSIS CATEGORIES

There are, in general, four types of benefits potentially associated with Navy MILCON projects, and each will be considered in turn. While the four benefit categories are by no means mutually exclusive, it is useful to consider them separately. The four categories are:

* direct cost savings

* efficiency/productivity increases

* other quantifiable output measures

* nonquantifiable output measures

D. DIRECT COST SAVINGS

Projects for modernization or rehabilitation of existing facilities sometimes generate real cost savings relative to the status quo of operations. These savings, usually in the form of a reduction in recurring operations and maintenance expenses during the projected economic life, represent a literal reduction in the funding level required to support an operation after some initial investment has been made. When the present value of these recurring savings exceeds the present value of the investment, the project "pays for itself" over the economic life. Stated another way, the investment is self-amortizing.

For such projects, the preparation of a Type I economic analysis is prescribed. The self-amortizing quality is demonstrated by a savings/investment ratio (SIR) greater than unity, calculated according to such formulae as equations (III-6), (III-6a), or (III-6b) in Subsection III-E. (More generally, the SIR may be calculated simply by executing in sequence steps 7-22 of Format A-1, Appendix D.)

Not all projects generating recurring cost savings relative to the status quo can support a SIR greater than unity, but a partial self-amortization may nevertheless be of interest to decision-makers and budget reviewers, and should be brought to their attention. Consider the following illustration:

EXAMPLE V-1: U. S. Naval Station, Anywhere, has been plagued over the last several years by repeated power blackouts due to an outmoded and overloaded transformer substation. The Public Works Officer (PWO) has investigated the situation and determined that the only alternative is to upgrade the power substation. (The local power company is unable to provide the power required and operational needs mandate an on-base source, whose present location is ideal and fully consistent with the station master plan.) Since this is the only feasible alternative, strictly speaking no formal economic analysis is required. (A defensible statement indicating the other alternatives investigated and the reasons for their infeasibility is required when only one alternative is considered to be feasible.) However, the PWO recognizes certain benefits potentially accruing from this project and has decided to portray them to the decision-maker in a benefit/cost analysis.

The public works planners have generated the following cost data for this project:

Investment	$500,000
Reduction in Recurring Annual Expenses	
1. Personnel (Maintenance) . . .	$ 20,000
2. Operations	10,000
TOTAL:	$30,000
Economic Life	25 years

This data translates into the following computations:

Total Recurring Annual Savings	$30,000
25 Year (Table B) Discount Factor . .	9.524
Total Discounted Savings	$286,000
Investment	$500,000
Savings/Investment Ratio (SIR)	0.57

This demonstrates that the project amortizes 57% of its investment in real, hard cash savings relative to current operations over the anticipated economic life. This information is important to the Navy and the taxpayer, and it should be included in the project data, even though there exists only one solution to this critical deficiency.

E. EFFICIENCY/PRODUCTIVITY INCREASES

Projects for modernization, rehabilitation, consolidation, and other related goals often generate an increase in efficiency of operations or productivity. Such increases are extremely beneficial and should be included in a benefit/cost analysis when they exist. Benefits of this type are frequently confused with direct cost savings because they are easily quantified in dollar terms. However, they are not equivalent, and the analyst should understand the fundamental difference clearly.

An increase in efficiency or productivity implies only one thing--the ability to do more work within the existing manpower/funding level. The only way to translate an efficiency/productivity increase into direct cost savings is to effect a reduction in force (RIF) which lowers the required funding level. However, a RIF is not usually

intended as the mandated result of a MILCON project, and thus some other means of quantifying efficiency/productivity benefits must be used.

The solution to the problem is really a simple matter of semantics. An efficiency/productivity increase which translates into a labor time saving of two man-years is a benefit whose value may be defined as what it would cost the Government to buy an additional two man-years of labor. This cost should be accelerated by the appropriate rate for leave and fringes because the value of the benefit should reflect the actual total cost to the Government of providing two man-years of work.

One very important caveat must be mentioned at this point. In order to claim an efficiency/productivity increase as a valid benefit, there must be a documented need for the increased workload capacity. In other words, there must be an alternative use to which the "new" manpower resources can be put, such as reducing a backlog of maintenance. Lacking this, there is no benefit--or at least no quantifiable benefit--derived from the project. Documentation of this fact must be complete and explicit in the benefit/cost analysis.

EXAMPLE V-2: The public works planners at NAVSTA, ANYWHERE, have identified additional efficiency/productivity benefits accruing from the transformer project of Example V-1. Since the existing substation serves the industrial area of the base, every time a power blackout occurs most of the base industrial functions come to a standstill.

The Assistant PWO (APWO) has conducted an extensive time and motion study to determine the impact of the power blackouts on industrial output. His detailed study revealed that over the past four years, total industrial downtime due to blackouts averaged 2.1 man-years per year. (This figure was deemed to be conservative in that it did not include an estimate of restart time necessary to resume interrupted project work after a power loss.) Average present annual salary of the personnel involved in the work interruptions is $14,820. Existing work backlog is more than sufficient to justify the need for full capacity operations.

The proposed project is expected to completely solve the current power problem, and thus provide an additional 2.1 man-years of industrial capacity with no increase in personnel. The value of this benefit is the cost the Navy would incur if it had to hire enough additional workers to provide 2.1 man-years of labor per year. Thus, the figure must be accelerated to account for both leave and fringes:

$$\text{Annual Benefits} = (2.1 \text{ man-years}) \times (\$14{,}820/\text{yr}) \times (1.51)$$

$$= \$47{,}000$$

This does not represent a direct savings, but a benefit whose value is $47,000 per year. Using this information the APWO calculated an efficiency-productivity/investment ratio (EPIR) according to the following formula:

$$\text{EPIR} = \frac{\text{P.V. of Efficiency/Productivity Benefits Generated}}{\text{P.V. of Investment Required}} \quad \ldots \text{(V-2)}$$

The computations follow:

Total Recurring Annual Benefits	$ 47,000
25 Year (Table B) Discount Factor	9.524
Total Discounted Benefits	$447,600
P.V. of Investment Required (see Example V-1)	$500,000
Efficiency-Productivity/Investment Ratio (EPIR)	0.90

In this particular case, the SIR and EPIR may be added together to obtain the total benefit/cost ratio (BCR). Thus:

SIR	0.57
EPIR	0.90
BCR	1.47

It should be noted that the benefit/cost ratio (BCR) was defined in most general terms as follows:

$$\text{BCR} = \frac{\text{Benefits}}{\text{Costs}} \quad \ldots \text{(see equation (V-1))}$$

It may be either dimensional or nondimensional, depending upon the terms in which the benefits are described. In the example above, the BCR was obtainable as the sum of the SIR and EPIR only because (a) the cost savings, efficiency/productivity increases, and project investment costs were all stated in terms of dollars, thereby yielding a consistent dimensionality between the two benefit measures, and (b) the two benefit measures (namely life cycle cost savings and increased efficiency/productivity) were distinct and nonoverlapping. This situation occurs frequently in MILCON projects whose goals are savings and productivity oriented.

F. OTHER QUANTIFIABLE OUTPUT MEASURES

Many investment decisions, especially in industrial areas, have a stated goal defined in terms of required output produced. The goal is not always quantified, but it often is susceptible to quantification and thus provides a potential measure of benefits associated with the investment. Military Construction Project justification provides a definition of objectives and speaks to these goals, but too frequently in a general rather than a specific manner. However, to be of real use to decision-makers and budget reviewers, project backup data should relate goals to quantifiable levels of output where possible. These output measures may be used as a measure of benefits accruing from the project since, by definition, the justification (expected benefit) for a project is in fact some product or service (output) required to fulfill a mission of the Navy.

This category of benefits applies most frequently to projects requiring a Type II economic analysis, in which alternative methods of satisfying a validated facility deficiency are compared. This comparison is facilitated by the computation of a form of benefit/cost ratio (BCR) for each alternative. The appropriate formulation of the BCR is as follows:

$$BCR = \frac{\text{Annual Benefit/Output Measure}}{\text{Uniform Annual Cost}} \qquad \text{. . . (V-3)}$$

In this expression, the uniform annual cost (UAC) is calculated as described in Subsection III-F and the annual benefit/output measure (ABOM) is merely a quantified statement of expected yearly output for the alternative under investigation.

Some examples of ABOM's follow:

* number of aircraft overhauled per year

* number of liberty-man-days generated per year (Cold Iron project)

* cubic meters of sewage treated per year

* number of sailors trained per year

* kilowatt-hours of electricity produced per year

* antennas overhauled and tested per year

This list is by no means exhaustive, but it should provide the analyst with a good perception of what a benefit measure is, and should assist him in formulating specific benefit measures tailored to his particular analytical problem. The following example of aircraft maintenance jobs performed illustrates the methodology employed for such benefit measures.

EXAMPLE V-3: Due to a Chief of Naval Operations (CNO) sponsored regional consolidation, the Naval Air Rework Facility at Naval Air Station, Elsewhere, has been assigned the responsibility of providing all the corrosion control maintenance for Atlantic Fleet P-3 Orions in the Northeast. The public works planners have undertaken a detailed feasibility/concept study and have determined that there exist only two reasonable alternative methods of satisfying this operational requirement:

1. Modify existing unused hangar space to accommodate the corrosion control function. Expected economic life: 25 years.

2. Demolish old hangar space and construct a new, highly efficient, semiautomated corrosion control facility. Expected economic life: 25 years.

The planning staff investigated all the relevant data for these alternatives and provided the following analysis:

ITEM	MODIFY	NEW-CONSTRUCT
Recurring Annual Expenses (Personnel, O&M, etc.)	$ 100,000	$ 85,000
25 Year Discount Factor	9.524	9.524
P.V. of Recurring Cost	$ 952,000	$ 810,000
Investment (Time Zero)	$2,000,000	$2,600,000
Total P.V. Cost	$2,952,000	$3,410,000
Uniform Annual Cost (UAC) (Discount Factor = 9.524)	$ 310,000	$ 358,000
Benefit (Output) (Maintenance Jobs Performed in terms of aircraft per year)	300/yr	375/yr
Benefit/Cost Ratio (BCR) (Completed Aircraft Maintenance Jobs per year per $1000)	0.97	1.05

Thus, although the new facility is more expensive, the benefit (output) per equivalent annual dollar expended is 8% higher than for the modification option, since:

$$\frac{1.05}{0.97} = 1.08.$$

The planning staff noted that the new construction alternative of Example V-3 is likely to have a more favorable effect on increasing aircraft life. The total number of P-3 aircraft (A/C) in the Northeast fleet is 200. Thus, with new construction this means a plane can undergo corrosion control about every 6.4 months, while with modification 8 months will be the minimum time between corrosion controls.

$$\text{NEW:} \quad \frac{200 \text{ A/C}}{375 \text{ A/C/Yr}} = 0.533 \text{ Yr./Maint.} = 6.4 \text{ Months/Maint.}$$

$$\text{MODIFY:} \quad \frac{200 \text{ A/C}}{300 \text{ A/C/Yr}} = 0.667 \text{ Yr./Maint.} = 8.0 \text{ Months/Maint.}$$

Although both maintenance cycles are acceptable to COMNAVAIRLANT, he acknowledges that more frequent corrosion control would be preferable due to the cumulative impact of salt air corrosion on airframes.

No significance should be attached to the fact that the computed BCR for the modification alternative is less than unity and the BCR for new construction exceeds unity. This is due entirely to the dimensional quality of the BCR and the arbitrarily chosen baseline (completed maintenance jobs per year per $1000.) The only valid comparison is between the two ratio measures. Their relationship to unity has no significance whatsoever. (The reader should not confuse this situation with that of a nondimensional BCR, such as the savings/investment ratio, in which the significance of unity is pivotal.)

Additionally, it should be noted that the various benefit/cost ratio techniques should be employed only when the order of magnitude of benefits and costs for alternatives under consideration is the same. If this is not the case, the BCR, like any other ratio measure, will obscure important information, and can prove to be definitely misleading.

Other quantifiable output measures expected of an alternative may fall into various areas depending on the kind of operation, program or system which is being analyzed. Some potential areas for quantifiable output measures are listed below. This list is not intended to be all inclusive; it is merely a guide in the effort to include all relevant benefits related to an alternative. Some of the areas in which these other benefits appear are:

Acceptability: Consider the alternative in terms of whether it may interfere with the operation of parallel organizations or the prerogatives of higher echelon organizations (consider customer satisfaction).

Accuracy: What is error rate? Measure errors per operating time period, number of errors per card punched, errors per hundred records, errors per 100 items produced, etc.

Availability: When can each system be delivered/implemented; when is it needed to meet proposed output schedules? What is the lead time for spare parts delivery?

Environmental and Community Economic Impact: (Refer to Subsection V-H, Externalities.)

Integrability: Consider how the workload and product of the organization will be affected by the changes necessitated by modification of existing facilities or equipment, technical data requirements, initial personnel training, warehouse space for raw goods or parts storage, etc.

Maintainability/Controllability: Has adequate human factors engineering been performed? When the system does fail, is it difficult to repair because of poor accessibility? A useful measure could be based on the average man-hours necessary for repairs over a given time period, i.e., downtime, or the crew rate necessary to control and maintain the system.

Manageability: Consider how the workload of the organization will be affected by increased or decreased supervision or inspection time as a result of the system. Man-days could be used as a measure; differences in kind of personnel might be a factor as well as availability of type needed.

Morale: Employee morale -- this could be measured by an opinion sample survey or by other indicators.

Operating Efficiency: At what rate does the system consume resources to achieve its outputs? For example, miles per gallon, copies per kilowatt-hour, mean days per shipment.

Production or Productivity: Number of commodities or items produced; or volume of output related to man-hours (i.e., number of components manufactured, hours flown or meals served; or number of items per man-hour.)

Quality: Will a better quality product/service be obtained? Could quality be graded, thus measurable? If not, a description of improvement could be given. What is the impact of the varied quality?

Reliability: This describes the system in terms of its probable failure rate. Useful measures may be mean-time-between-failure, the number of service calls per year, percent refusals per warehouse requests.

Safety: Number of accidents, hazards involved.

Security: Is security built in? Will more precautions be needed? More guards? Are thefts more likely?

G. NONQUANTIFIABLE OUTPUT MEASURES

Despite the analyst's best efforts to develop quantitative measures of benefits, he sometimes is faced with a situation which simply does not lend itself to such analysis. Certain projects may provide benefits such as increased retention rates, improved morale, better troop habitability, and other similar qualitative advantages. Although they are most difficult to assess, these benefits should be documented and portrayed in the economic analysis.

In most such instances the analyst must resort to written qualitative benefit descriptions. This is the least preferred method of analyzing benefits due to its inherent lack of precision. However, under certain conditions this method must suffice, and if the following guidelines are observed, qualitative statements can make a positive contribution:

1. Identify all benefits attendant to each alternative under consideration. Give complete details.

2. Identify benefits common in kind but not in extent or degree among alternatives. Explain differences in detail.

3. Avoid platitudes. All prospective projects are worthwhile in that they support national defense, and statements to this effect are unnecessary. Platitudinous statements serve only to cloud the decision-making environment. Following these general guidelines faithfully will enhance the value of benefit/cost analyses and make the job of the decision-maker easier.

H. EXTERNALITIES

Usually it is adequate to perform an economic analysis of a Navy decision solely from the viewpoint of the U.S. Government (as discussed in Subsection IV-C). The basic output of Navy investments, national defense, is a <u>public good</u> -- that is, once it is provided to someone it is provided to <u>everyone</u> in the country. However, other types of outputs may result from Navy investments. When computing the benefit/cost ratio, costs are usually regarded as the resources or <u>inputs</u> necessary to implement an alternative while benefits are <u>regarded</u> as results or <u>outputs</u> from implementing that alternative, so the BCR may be <u>equivalently</u> formulated as:

$$BCR = \frac{\text{Outputs}}{\text{Inputs}} \qquad \text{. . . (V-4)}$$

(Strictly speaking, a savings is not an output; it is a difference in inputs. However, a savings may be the result or yield of an investment, and it is useful to consider the SIR as a special case of the BCR as formulated in equation (V-4).)

It is obvious that outputs may be negative--they may be disbenefits rather than benefits.

Externalities (also referred to as external effects or spillovers) are an important class of outputs that may be benefits or disbenefits. Externalities are outputs involuntarily received by or imposed on a person or group as a result of an action by another and over which the recipient has no control.

Air pollution is an example of an externality that is a disbenefit. The recipients accrue health, aesthetic, etc., disbenefits from a polluter for which they receive no compensation. For most facilities investment decisions, it is not necessary to analyze in depth externalities such as environmental impacts and community economic impacts as part of the economic analysis; these aspects of the alternatives are usually treated in detail as part of the Environmental Impact Assessment/Environmental Impact Statement process. However, the mention of anticipated impacts (both quantified and unquantified) in the economic analysis documentation is appropriate.

An example of an externality that should be fully treated in a facilities related economic analysis occurs in the comparison of providing medical care using a Government facility versus through Civilian Health and Medical Program of the Uniformed Services (CHAMPUS) payments. If the CHAMPUS alternative is chosen, the eligible people involved must pay the difference between the bill for the medical care and the (lower) CHAMPUS reimbursement provided. In this case, the differential cost which must be borne by military personnel and their families should be estimated and provided as supplemental information in the economic analysis documentation. Similarly, in the comparison of MILCON versus BAQ for provision of housing, if BAQ payments are inadequate to obtain rental housing on the local market, the impact on the personnel involved should be estimated and provided separately from the NPV of costs to the Government. Such impacts are important to the Navy since they affect the effective compensation of military personnel.

I. BENEFIT DOCUMENTATION

No specific format is prescribed for documentation of benefit analysis information, but the analyst is encouraged to use Format B, exhibited in Appendix C, when appropriate. Format B, for all intents and purposes, is a "blank page" on which may be enumerated any and all information the analyst deems appropriate. More important than the form, however, is the content, and in the case of benefits, content is critical. No economic analysis is truly complete unless it addresses benefits attending all the alternatives considered.

One other simple documentation format suggested for summarizing benefits is a matrix of benefits versus alternatives. A list of all benefits can be made and easily compared among alternatives. This matrix is recommended as an additional summary of the outputs listed on Format B, paragraph 8.

In addition to benefits, the analyst should also include information concerning any negative or deleterious aspects of alternatives, quantified where possible. This information is important to the decision-maker and possibly to the community at large, and may be a determining factor in deciding between possible investment alternatives.

J. SUMMARY

This section has outlined a number of techniques for evaluating and portraying benefits in a benefit/cost analysis framework. The techniques mentioned are by no means exhaustive in their scope, but rather are suggestive of the approach the analyst should follow in evaluating alternatives under consideration. The analyst is encouraged to use not only those techniques mentioned, but also any others he may feel appropriate. If a unique methodology is employed, the analyst should explain and justify his work thoroughly. Whatever methodology he employs, the analyst is required to document his source data adequately. This mandate has been mentioned previously with respect to costs, and it holds true just as fundamentally for benefits.

VI. SENSITIVITY ANALYSIS

"If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts he shall end in certainties."

- Francis Bacon

A. INTRODUCTION

The quotation above reflects the problem that analysts face dealing with the real world. Economic analyses are built from data as a house is built of bricks, but an accumulation of data is no more an analysis than a pile of bricks is a house. Regardless of the care devoted to data collection, there is always a distinct possibility that the data will be misleading. Estimates and forecasts may be inaccurate. Data may be accurate but descriptive of a different situation. When the data are in doubt, as is often the case, the analyst must consider the consequences of its use.

Data analysis and forecasts therefore represent the analyst's best judgment on the way in which events will occur in the future. There are always uncertainties about the future. However, these uncertainties are no reason for the analyst not to make the best estimates that he/she can and to base conclusions upon them. Nevertheless, a decision among alternatives often can be made more confidently if the decision-maker can see whether the conclusion is sensitive to moderate changes in data forecasts. Sensitivity analysis provides this extra dimension to an economic analysis.

B. CONCEPT OF SENSITIVITY ANALYSIS

Since uncertainty is almost universally present in economic decision-making, some type of sensitivity analysis should always be considered when performing an economic analysis. When doubts and uncertainties enter an analysis, it is necessary to test the sensitivity of the results to the cost estimates or other assumptions in order to portray a complete picture to the decision-maker. The sensitivity of a decision is investigated by inserting a range of estimates for critical elements; a sensitivity analysis measures the relative magnitude of change in one or more elements of an economic comparison that will reorder a ranking of alternatives.

In preceding sections of this handbook, examples have involved choosing among alternatives in which a single set of cost estimates was specified. When conducting an economic analysis, the stated cost estimates represent someone's best judgment on the way in which expected future cash flows will occur. Future costs, salvage value, economic life and other data are estimated based on reasonable expectations. They are

rarely known with complete certainty, and the degree of uncertainty generally increases with the time interval between the estimate and the occurrence. In addition to recognizing uncertainty during the estimating process, it is prudent to examine how one or more of the variables will affect the choice of alternatives if values for these variables would be higher or lower than the baseline estimate (best estimate).

It is obvious that if some cost elements were sufficiently different, the ranking of alternatives would be different. On the other hand, radical changes could be made to other elements without changing the decision. For example, if one particular element can be varied over a wide range of values without affecting the decision, then the decision is said to be insensitive to uncertainties regarding that particular element. However, if a small change in the estimate of one element will alter the decision, the decision is said to be very sensitive to changes in the estimate of that element.

An established semantic tradition partitions sensitivity analysis into two branches, <u>risk analysis</u> and <u>uncertainty analysis</u>. Risk analysis addresses variables which have a known (or estimated) probability distribution of occurrence; in this context, the systematic techniques of applied probability and statistics may be used to great advantage. Uncertainty analysis concerns itself with situations in which there is not enough information to determine probability or frequency distributions for the variables involved.

The analyst contemplating a sensitivity analysis should begin by asking himself the following general questions:

1. Which input(s) should be tested?

2. Once the test variables have been selected and a sensitivity analysis performed, how should the results be formatted in a submission to the decision-maker?

As with economic analysis in general, the watchword in sensitivity analysis is common sense. If the preference ranking of alternatives establishes one option as markedly superior to the rest, the analyst should not be overly concerned about the sensitivity of this choice to nominal variations in the values of input parameters. It is when an economic choice is <u>not</u> clear-cut that further investigation is most appropriate. The application of sensitivity analysis is recommended as an iterative process to refine the analysis. Rather than developing a formal theory, the remainder of this section illustrates the rationale and basic techniques most commonly applied in sensitivity analysis via a series of examples.

C. <u>ONE VARIABLE UNCERTAINTY TESTS</u>

As a first step, sensitivity analysis should be applied to the dominant cost factors (i.e., those which have the most significant impact

on the total net present value (NPV) costs and/or benefits of a given alternative). Since many of the input cost factors are linear, using the best estimate (or expected value) as a starting point, one may easily derive another point or points and to graph the relationships between each input factor and the total NPV cost, as shown in Example VI-1 below.

EXAMPLE VI-1: OPERATION SECONDARY Uncertainty Analysis - Alternative A's NPV cost (see Example III-6) is plotted in Figure VI-1 as a function of varying levels of inputs. The inputs specifically considered are initial construction (acquisition) cost, recurring annual cost, and economic life, for which the original values were $100K, $5K, and 20 years, respectively. As can be seen, within a given percentage range, fluctuations in construction cost induce correspondingly greater changes in PV life cycle cost than do fluctuations in recurring annual cost or economic life. In this sense, construction cost dominates the other two input variables.

Remarks:

1. Note that NPV cost, when plotted as a function of construction cost, yields the steepest of the three curves. It is true in general that the steeper the curve, the more dominant is the corresponding input variable. (As he gains experience, the analyst should find that in many cases he will be able to identify the most dominant variables without actually having to plot curves.)

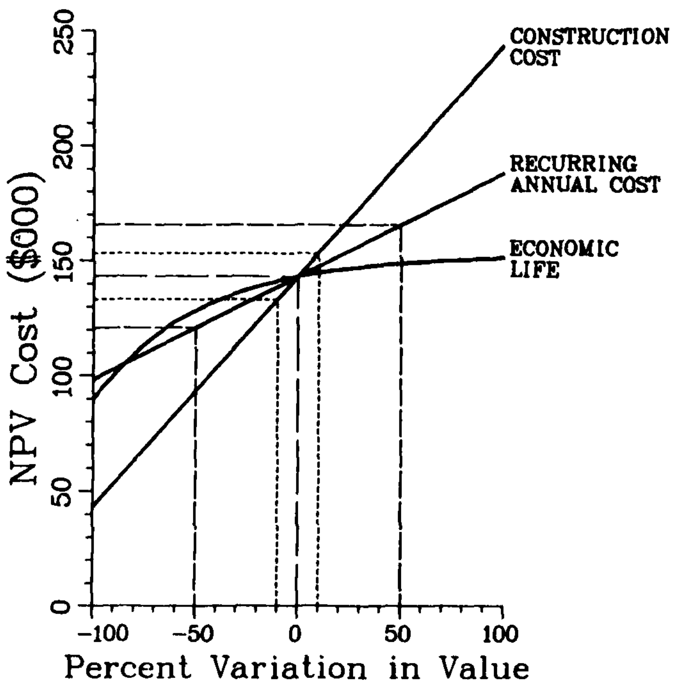


FIGURE VI-1

2. Nonetheless, construction cost is not necessarily the most critical input variable in this example. Suppose, e.g., that the actual construction cost is expected to be within ± 10% of the $100K estimate, but that the range of uncertainty in the $5K recurring annual (O&M) cost estimate is ± 50%. Careful scrutiny of Figure VI-1 indicates that, subject to these conditions, the potential impact of recurring annual cost on total PV life cycle cost is actually the greater. Thus the choice of input variable(s) for sensitivity testing may depend not only upon relative dominance, but also upon the degree of confidence which can be placed in the estimate(s).

The reader should observe from Example V-1 that while total PV life cycle cost is a linear function of construction cost and annual cost, it is a nonlinear function of economic life. This is because of the diminishing trend of Table A discount factors as we proceed further into the future. Due to the concavity of the curve, economic life is more dominant than annual recurring cost in the approximate range -100% to -50% (0-10 years), and less dominant thereafter (because it is less steep). In fact, the curve tends to a horizontal asymptote as it proceeds to the right, which can be seen in Figure VI-1.

It should be further noted from Figure VI-1 that increasing the economic life beyond the range 20-25 years (0 to 25% on the horizontal scale) has but a slight impact on the total PV life cycle cost. This situation is in fact typical, and it bears implications for economic life guidelines. The contention is sometimes made that a new permanent building should have an economic life of 40 or 50 years instead of the 25 years prescribed earlier. Such an assertion fails to acknowledge the constraint of mission life on economic life--it is simply unrealistic to project a requirement much more than 25 years into the future. Due to obsolesence or changing criteria, technological life may be a constraining factor also. Quite apart from this consideration, Figure VI-1 suggests that the sheer mathematics of discounting makes 25 years a practical choice for the maximum economic life allowable. Relative to an interest rate of 10%, the difference between total present value life cycle costs computed for a 25 year life and costs computed over any longer period is not significant.

Another example of a one variable uncertainty analysis is discussed in Example VI-2, which examines a range of SIR values over the range of uncertainty.

EXAMPLE VI-2: OPERATION PRIMARY Uncertainty Analysis (Example III-7). Determine how high the annual costs of the proposed alternative (B) can be before it becomes "unprofitable" to undertake the project.

SOLUTION: The data of Example III-7 is redisplayed below for convenience:

Economic Life	15 years
Alternative A (Status Quo):	
Investment Cost	none
Recurring Annual Cost	\$40K
Alternative B (Proposed):	
Investment Cost	\$60K
Recurring Annual Cost	\$30K

Annual savings of B relative to A were thus \$40K - \$30K = \$10K, and the discounted savings/investment ratio over the 15 year economic life was computed as follows:

$$SIR = \frac{\$10K(7.980)}{\$60K} = \frac{\$79.8K}{\$60K} = 1.33$$

In order to test the sensitivity of the savings/investment ratio to the annual cost in Alternative B, we represent that cost as a variable (say X) and rewrite the SIR equation as follows:

$$SIR = \frac{(\$40K - X)(7.980)}{\$60K}$$

The minimal SIR necessary for "profitability" of the proposed alternative (B) is 1.0. Making this substitution and solving for X, we have:

$$1 = \frac{(\$40K - X)(7.98)}{\$60K}$$

$$(\$40K - X)(7.98) = \$60K$$

$$\$40K - X = \frac{\$60K}{7.98} = \$7.5K$$

$$X = \$32.5K$$

Thus, the proposed alternative is economically worth undertaking so long as its annual cost does not exceed \$32.5K.

REMARK:

The above sensitivity analysis may easily be expanded into a graphical portrayal of the SIR function over the entire range of possible

Alternative B annual costs. The rewritten SIR equation is a linear equation, and two points on its graph are already known:

X = $30K, SIR = 1.33

X = 32.5K, SIR = 1.0

A plot of SIR against Alternative B annual cost is shown in Figure VI-2 below.

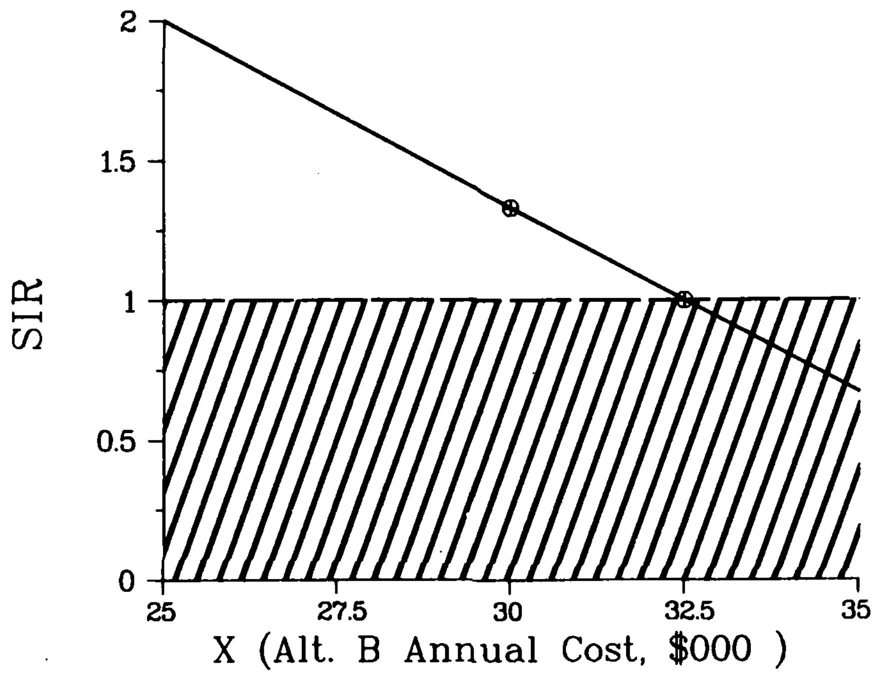


FIGURE VI-2

The minimal level of profitability (SIR = 1) is shown by the dashed horizontal line, and the SIR's below this line (i.e., in the shaded region) do not warrant funding of the project. This type of graphical presentation is often a very effective way to communicate sensitivity analysis information to the decision-maker.

D. BREAKEVEN ANALYSIS

The breakeven type of analysis is useful in economic analysis when uncertainty is concentrated in only one of the aspects which must be forecast. When a large change in the value of a factor will not change

the choice of alternative, the decision is not sensitive to variations in the value of this factor. Breakeven calculations may then be a simple means of verifying the ranking of alternatives.

A breakeven calculation is made by equating the costs of alternative courses of action, keeping the uncertain factor as an unknown in the equation, and solving for the value of the unknown factor which will make the alternatives equal.

If the expected range or best estimate of the unknown factor is definitely larger or smaller than the breakeven value, the ranking is insensitive to the factor and the lower cost alternative can be chosen with a high degree of confidence and without carefully estimating values for the insensitive factor. The wide applicability of breakeven analysis can be seen in the following three examples.

EXAMPLE VI-3: An R & D Testing Office requires a new testing device. It is considering a semiautomatic device (A) or a fully automatic model, device (B).

Device A will cost \$8,000, will have an expected life of 15 years with no salvage value, and will have maintenance and operating costs of \$2,000 a year, plus testing use costs of \$0.20 per item tested.

Device B will cost \$20,000, will have an expected life of 10 years with no salvage value, and will have maintenance and operating costs of \$3,000 a year, plus testing use costs of \$0.08 per item tested.

NOTE: The R & D Testing Office is very uncertain as to the annual number of tests that will be made.

SOLUTION: An equal cost analysis may be helpful in this case. At what testing volume will the annual costs be the same, regardless of whether the semiautomatic or fully automatic device is purchased?

Let N represent the number of tests made. Equivalent uniform annual cost (UAC_A) of using device (A) is:

$$UAC_A = \frac{\$8,000}{B_{15}} + \$2,000 + \$0.20\ N$$

where B_{15} is the Table B factor for 15 years.

Equivalent uniform annual cost (UAC_B) of using device (B) is:

$$UAC_B = \frac{\$20,000}{B_{10}} + \$3,000 + \$0.08\ N$$

where B_{10} is the Table B factor for 10 years.

Equating the annual costs, we have:

$$UAC_A = UAC_B$$

$$\frac{\$8,000}{7.980} + \$2000 + \$.20N = \frac{\$20,000}{6.447} + \$3,000 + \$.08\ N$$

Solving for N we have:

$$N = 25,831$$

REMARKS: Equivalent uniform annual cost will be the same using the semiautomatic or the fully automatic testing device if the number of tests performed per year is 25,831. If more than 25,831 tests are expected, the fully automatic device is more economical. If less than 25,831 tests are expected, the semiautomatic device is more economical.

The headquarters' best estimate of future annual testing requirements is between 60,000 and 120,000 items per year. Therefore, despite the uncertainty and wide range of estimates, the more economical alternative is device (B) for fully automatic testing.

EXAMPLE VI-4: For the MILCON and LEASE options diagrammed in Figure VI-3 determine:

a. Which alternative has the lesser total NPV cost over the indicated economic life of 25 years;

b. The breakeven economic life, i.e., the period over which total NPV costs for the two alternatives would be the same.

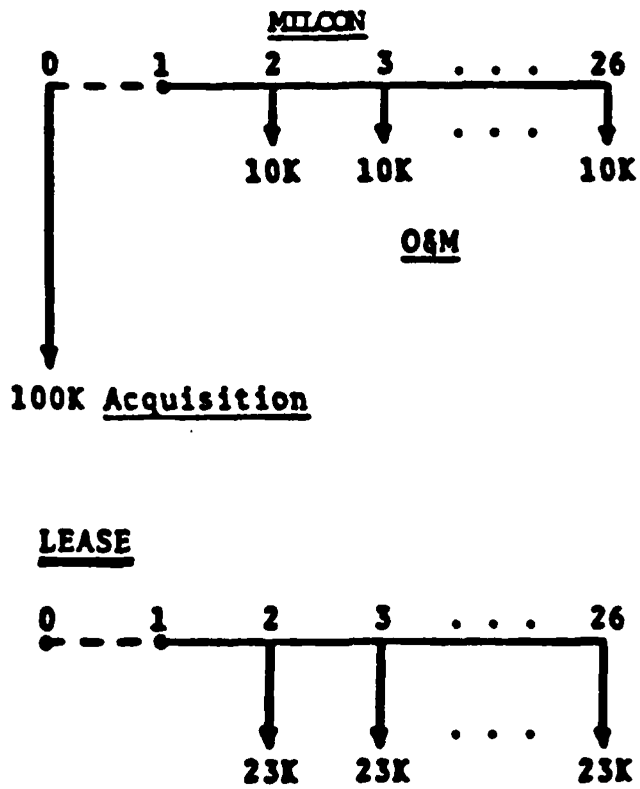


FIGURE VI-3

DISCUSSION: The cash flow diagrams of Figure VI-3 reflect an increasingly accepted treatment of lead time. The presumption here is that in the MILCON alternative, at least a year will elapse between obligation of construction funds and the facility's beneficial occupancy date (BOD). Accordingly, the time baseline is taken as the time of obligation, and a full year intervenes before recurring annual costs begin.

NOTE:. The economic life of the LEASE alternative has been slipped back a year to coincide with the delayed economic life of the MILCON alternative. This does not necessarily represent the actual situation--it might well be possible to negotiate a lease for occupancy during the first year. The slippage is purely an analytical device, suggested in DODINST 7041.3, which indirectly penalizes that alternative having the longer lead time (in this case, MILCON). The penalty is exacted by the application of smaller discount factors to the LEASE costs (Years 2-26 instead of Years 1-25), thereby making the LEASE alternative appear relatively more favorable.

SOLUTION: Total NPV costs for the two alternatives are as follows:

NPV (MILCON) = \$100K(1.000) + \$10K(9.612 - 0.954)

= \$186.6K

NPV (LEASE) = \$23K(9.612 - 0.954) = \$23K(8.658)

= \$199.1K

(Here, 9.612 and 0.954 are the 26th and 1st year cumulative discount factors, respectively, taken from Table B, Appendix E.)

One method of estimating the breakeven economic life is to adopt a graphical approach. To this end, some additional sample NPV calculations are presented below:

20 YEAR ECONOMIC LIFE

NPV (MILCON) = \$100K(1.000) + \$10K(9.074 - 0.954)

= \$181.2K

NPV (LEASE) = \$23K(9.074 - 0.954) = \$23K(8.120)

= \$186.8K

15 YEAR ECONOMIC LIFE

NPV (MILCON) = \$100K(1.000) + \$10K(8.209 - 0.954)

= \$172.6K

NPV (LEASE) = \$23K(8.209 - 0.954) = \$23K(7.255)

= \$166.9K

10 YEAR ECONOMIC LIFE

NPV (MILCON) = \$100K(1.000) + \$10K(6.815 - 0.954)

= \$158.6K

NPV (LEASE) = \$23K(6.815 - 0.954) = \$23K(5.861)

= \$134.8K

Observe that the economic decision changes (e.g., breakeven point occurs) somewhere between 15 and 20 years. The results of these NPV calculations

are plotted in Figure VI-4. When the cost points for each alternative are joined by smooth curves, the impact of economic life can readily be diagnosed. It is apparent from the figure that the breakeven period is approximately 17 years.

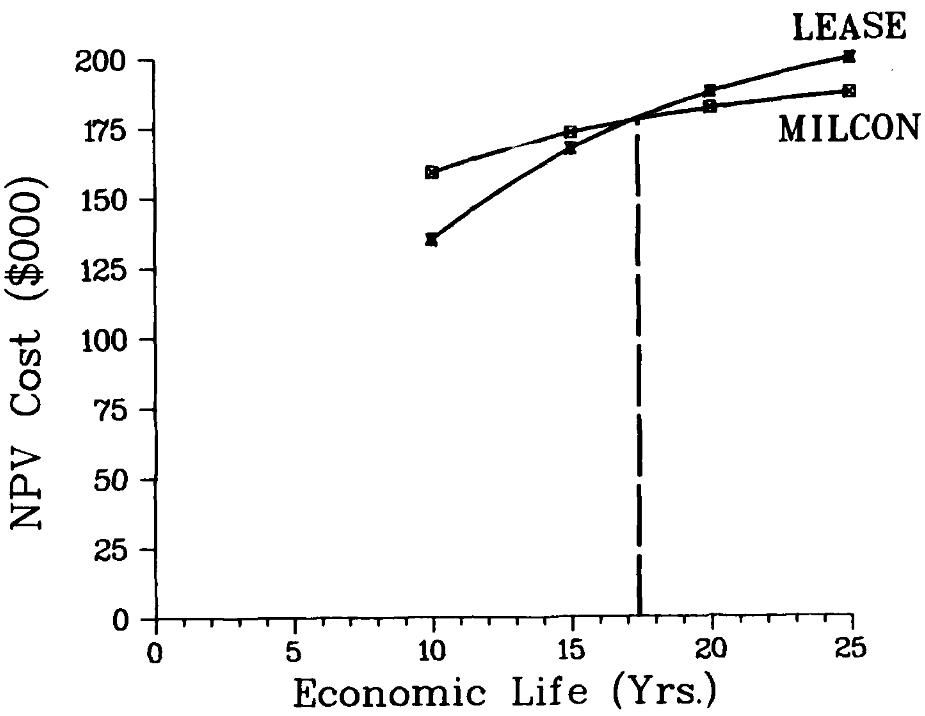


FIGURE VI-4

REMARK: An algebraic approach could also be employed to determine the breakeven economic life. If N denotes the duration of project life in years, then for breakeven we must have equivalence of present value life cycle costs as expressed in the following equation:

$$\text{NPV (MILCON)} = \text{NPV (LEASE)}$$

$$\$100K + \$10K\,(B_N - B_1) = \$23K(B_N - B_1)$$

Here B_1 and B_N are the 1st and Nth year Table B factors, respectively (Appendix E). Substituting $B_1 = 0.954$ and solving for B_N yields:

$$(\$23K - \$10K)(B_N - 0.954) = \$100K$$

$$(\$13K)(B_N - 0.954) = \$100K$$

$$B_N - 0.954 = \frac{\$100K}{\$13K} = 7.692$$

$$B_N = 7.692 + 0.954 = 8.646$$

Now from Table B, Appendix E,

$$B_{18} = 8.605, \qquad B_{19} = 8.777$$

so the project life N is between 18 and 19 years. On the basis of a linear interpolation between these two factors, we arrive at the approximation:

$$N = 18.2 \text{ years}$$

Subtracting the one year lead time from this figure gives 17.2 years, which is in good agreement with the graphical estimate of economic life in Figure VI-4.

The portrayal in Figure VI-4 is a logical sequel to a dominance test such as that shown in Figure VI-1. Figure VI-1 examines the sensitivity of <u>a single alternative</u> to variations in several inputs. In Figure VI-4, <u>one input has been selected</u> (either because of its dominance or extreme uncertainty in its estimate, or perhaps both), and the sensitivities of <u>both</u> alternatives to this input are plotted on the same graph. The <u>intersection</u> of the two curves in Figure VI-4 is known as a <u>decision point</u> or <u>breakeven point</u>. The same type of graphical approach <u>is often used in cost/volume/profit</u> analysis for a private firm.

If the economic life is to be 25 years, as originally assumed in Example VI-4, then MILCON is preferable to the LEASE alternative. It might be, however, that a general climate of base closures and troop strength reductions would raise some doubt about the validity of a 25 year facility requirement. If there is a possibility that the economic life will be appreciably <u>less</u> than 25 years, then the decision-maker, on the basis of the <u>information</u> portrayed in Figure VI-4, might seriously consider leasing instead of MILCON.

Another application of breakeven analysis to verify a benefit/cost ratio with uncertainties of annual cost is shown in Example VI-5.

<u>EXAMPLE VI-5</u>: Perform a sensitivity analysis of the recurring annual <u>cost total</u> for the NEW-CONSTRUCT Alternative of Example V-3, and determine the breakeven point.

SOLUTION: The benefit/cost ratio (BCR) for the MODIFY alternative was found to be 0.97. The essential data for the NEW-CONSTRUCT alternative is reproduced below:

Economic Life	25 years
Investment Cost (Year 0).	\$2,600K
Recurring Annual Expense.	\$ 85K
Benefit/Output (Maint. Jobs). . .	375/yr

For the required sensitivity analysis, the recurring annual cost will be treated as a variable (say Y). The uniform annual cost of the NEW-CONSTRUCT alternative is then:

$$UAC_{NC} = \frac{\$2{,}600K + Y(9.524)}{9.524} = \$273.0K + Y,$$

which leads to the following benefit/cost ratio (see Example V-3):

$$BCR_{NC} = \frac{ABOM_{NC}}{UAC_{NC}} = \frac{375}{273 + Y} \quad \text{(Maint. Jobs/yr/\$1000 UAC).}$$

Some sample BCR's are found by solving for different values of Y, as shown in the table below:

TABLE VI-1

Y	$UAC_{NC} = 273 + Y$	$BCR_{NC} = \frac{375}{UAC_{NC}}$
\$ 85K	\$358K	1.047
\$100K	\$373K	1.005
\$115K	\$388K	0.966
\$130K	\$403K	0.931

A plot of these points appears in Figure VI-5.

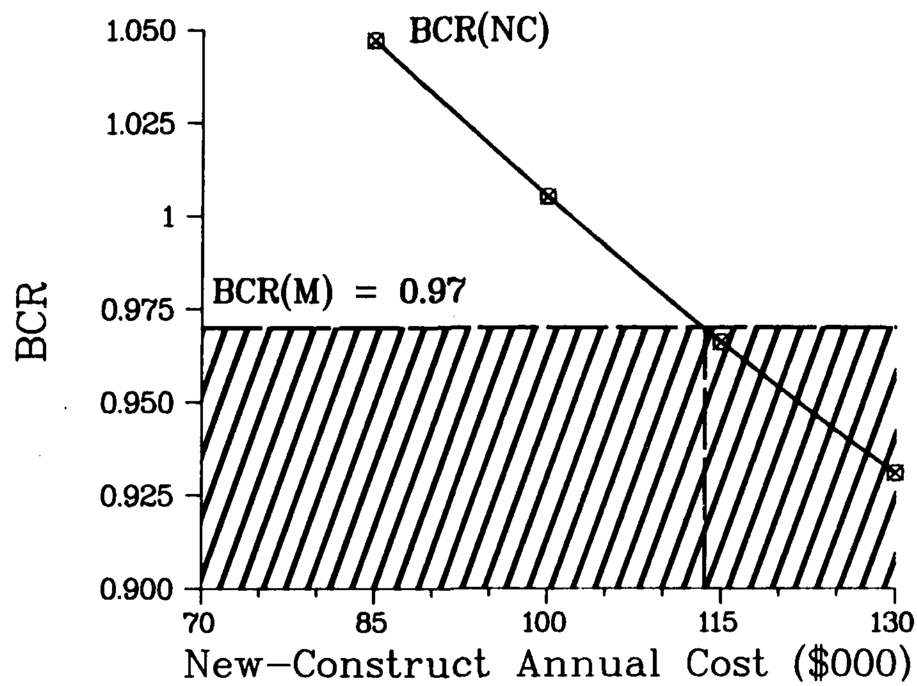


FIGURE VI-5

It can be seen that the annual expenses associated with the NEW-CONSTRUCT alternative can range almost up to $115K before it becomes less cost effective than the MODIFY alternative.

A precise determination of breakeven NEW-CONSTRUCT annual recurring costs can be made by equating the BCR expression of the (BCR) equation to 0.97 (the benefit/cost ratio for the MODIFY alternative) and solving for the unknown Y. As the reader may verify, the upper threshold is $113.6K.

E. TWO VARIABLE UNCERTAINTY TESTS

The outcome of an economic analysis is frequently sensitive to more than one input or assumption. The graphical techniques developed in the previous subsection may be extended to treat two variables simultaneously. Three illustrations follow.

EXAMPLE VI-6: Test the sensitivity of the SIR in Operation PRIMARY (Example III-7) to simultaneous variations in the Alternative B annual costs and the economic life.

SOLUTION: Here Example VI-2 serves as a point of departure. The SIR calculations of that example may be repeated for several prospective economic life periods. The following set of economic lives might be construed as representative of reasonable fluctuations about the "best guess" of 15 years (the economic life assumed in the original study):

10 years
13 years
15 years
17 years
20 years

With the Alternative B annual cost treated as a variable (X), the SIR equations for these economic lives are as follows:

10 years: $\text{SIR} = \dfrac{(\$40\text{K} - \text{X})(6.477)}{\$60\text{K}}$

13 years: $\text{SIR} = \dfrac{(\$40\text{K} - \text{X})(7.453)}{\$60\text{K}}$

15 years: $\text{SIR} = \dfrac{(\$40\text{K} - \text{X})(7.980)}{\$60\text{K}}$

17 years: $\text{SIR} = \dfrac{(\$40\text{K} - \text{X})(8.416)}{\$60\text{K}}$

20 years: $\text{SIR} = \dfrac{(\$40\text{K} - \text{X})(8.933)}{\$60\text{K}}$

(These equations are derived in the same manner as the SIR equation in Example VI-2; 6.447, 7.453, 7.980, 8.416, and 8.933 are the Appendix E Table B factors for 10 years, 13 years, 15 years, 17 years, and 20 years, respectively.)

Each of the above equations may be graphed in the same fashion as was the SIR equation in Figure VI-2. Figure VI-6 below shows a plot of all five equations on the same set of axes. Each curve is a straight line which, for the indicated economic life, represents the SIR as a function of the Alternative B annual cost. In the figure, vertical lines are plotted for each annual cost in the critical \$30K - \$34K range. The intersection of these reference lines with the various SIR plots determines a lattice of SIR points. For a given economic life and annual cost, one can tell by inspection whether or not Alternative B is economically justified--it is if, and only if, the SIR point lies above the SIR = 1.0 threshold. Moreover, visual interpolation between designated economic lives and annual costs is possible. For example, if the actual economic life were to be 12 years and the Alternative B annual cost, \$30.5K, then the SIR would be approximately 1.12 (see point A in Figure VI-6).

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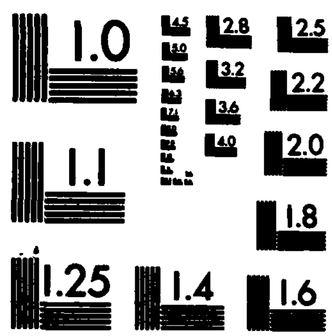


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

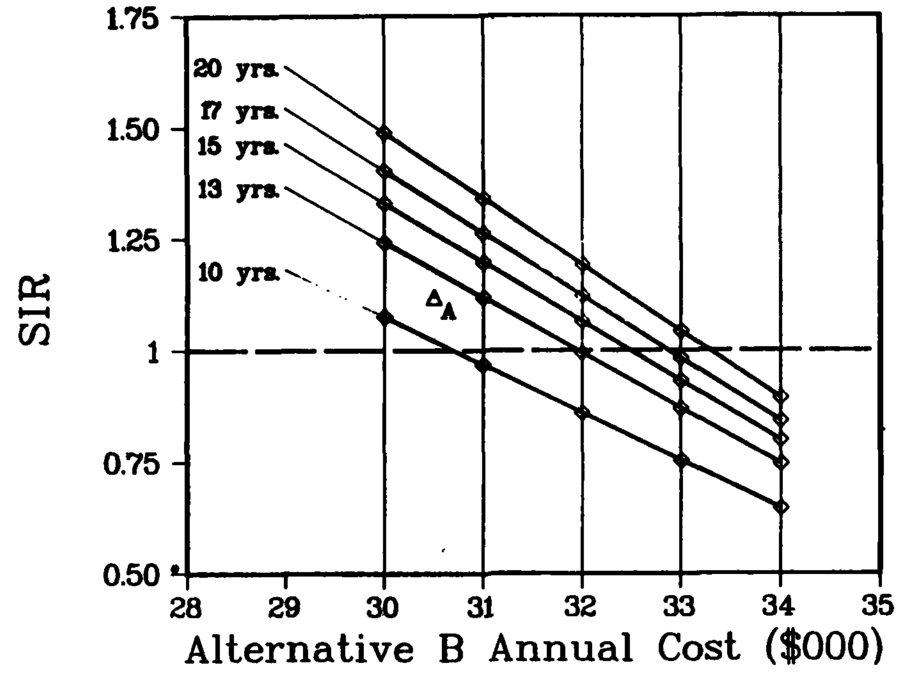


FIGURE VI-6

EXAMPLE VI-7: Test the sensitivity of the PV life cycle MILCON cost, Example VI-4, to simultaneous variations in annual O&M costs and acquisition cost.

SOLUTION: If we denote the acquisition (MILCON) cost by A and the recurring annual O & M expense by R, total NPV life cycle MILCON cost is given by:

$$NPV = A + (8.658)R$$

(Refer to the computations in the solution to Example VI-4.) Figure VI-7 shows plots of total NPV life cycle MILCON cost for various combinations of acquisition and recurring costs. Here the annual O & M cost is plotted on the horizontal axis and the acquisition cost A is shown at increments of $10K from $80K to $120K. The lattice of PV life cycle cost

points readily indicates for which combinations of acquisition cost and annual cost MILCON is economically preferable to leasing. The encircled point represents the "best guesses" (A = \$100K, R = \$10K) used in the original analysis.

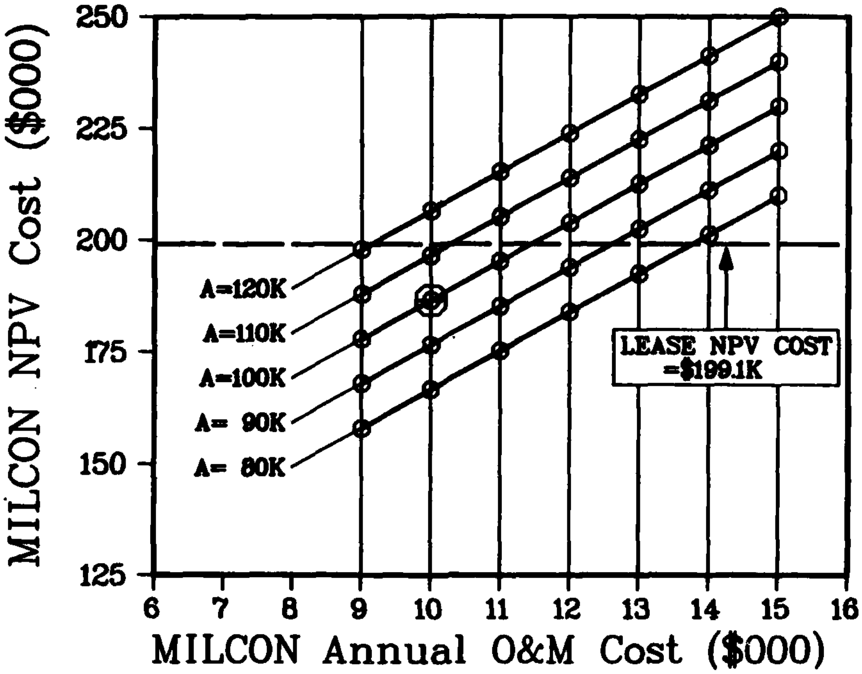


FIGURE VI-7

EXAMPLE VI-8 (Bivariate Breakeven Analysis): In Example VI-4 determine which combinations of economic life and MILCON annual costs equate total NPV life cycle costs of the MILCON and LEASE alternatives.

SOLUTION: The calculations in Example VI-4 serve as an appropriate point of departure. Denote the recurring annual (O&M) cost of the MILCON alternative by R. Then we have the following:

25 YEAR ECONOMIC LIFE

NPV(LEASE) = \$199.1K

NPV(MILCON) = \$100K + 8.658R

NPV(LEASE) = NPV(MILCON) yields R = \$11.4K (breakeven)

20 YEAR ECONOMIC LIFE

NPV(LEASE) = \$186.8K

NPV(MILCON) = \$100K + 8.120R

NPV(LEASE) = NPV(MILCON) yields R = \$10.7K (breakeven)

15 YEAR ECONOMIC LIFE

NPV(LEASE) = \$166.9K

NPV(MILCON) = \$100K + 7.255R

NPV(LEASE) = NPV(MILCON) yields R = \$9.2K (breakeven)

10 YEAR ECONOMIC LIFE

NPV(LEASE) = \$134.8K

NPV(MILCON) = \$100K + 5.861R

NPV(LEASE) = NPV(MILCON) yields R = \$5.9K (breakeven)

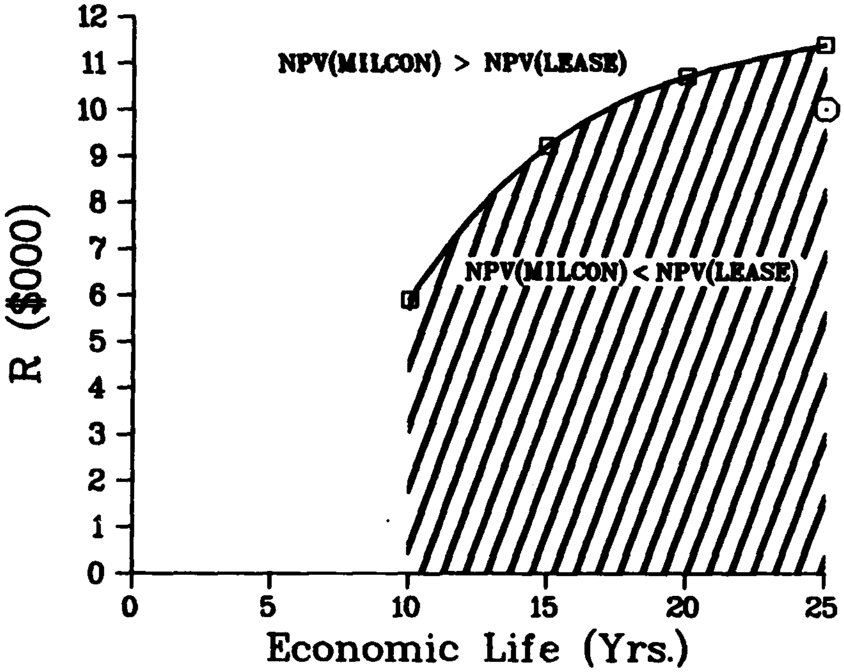


FIGURE VI-8

These breakeven combinations are graphed in Figure VI-8, which plots economic life against the recurring annual cost R of the MILCON alternative. The smooth curve joining these points is a breakeven curve--any point on this curve represents an economic life/ MILCON annual cost combination for which total PV life cycle costs of the MILCON and LEASE alternatives are the same. (Because of this characteristic, the breakeven curve is a two dimensional (bivariate) analogue of the breakeven point (such as the one plotted in Figure VI-4).)

The breakeven curve of Figure VI-8 partitions economic life/MILCON annual cost space into two regions. All points in the shaded region represent economic life/annual cost combinations for which PV life cycle MILCON cost is less than PV life cycle lease cost. (The encircled point in this region corresponds to values taken in the original comparison in Example VI-4: economic life = 25 years and R = $10K.) In the clear region, the LEASE alternative is economically preferable to the MILCON alternative. The more remote a given point is from the indifference curve, the greater the economic advantage enjoyed by the one alternative over the other (for the indicated economic life and MILCON annual cost).

F. EXPECTED VALUE

In some cases the analyst has quantitative information about the probabilities of various possible outcomes of an alternative; that is, there is enough information to make an estimate of what the relative frequency of an outcome would be if numerous trials were made. While the theories of probability and statistical inference are outside the scope of this handbook, probabilistic methods are often applicable in economic analyses. One simple technique that is frequently useful is expected value. An expected value characterizes a random variable and its probability distribution. The expected value is simply a weighted average that represents the average outcome that would be realized if the alternative were implemented many times. For a set of n possible outcomes, where P_i is the probability of outcome i, and W_i is the worth or value of outcome i, the expected value E is given by the summation of the products of the probabilities and their corresponding worths, or

$$E = P_1W_1 + P_2W_2 + P_3W_3 + \ldots + P_nW_n. \qquad \ldots \text{(VI-1)}$$

This equation may be equivalently written in summation notation as

$$E = \sum_{i=1}^{n} P_iW_i. \qquad \ldots \text{(VI-2)}$$

EXAMPLE VI-9: In a proposed automated widget system with an 8 year economic life there is a critical component with a shorter physical life. Replacement of this component will be required in Project Year 5. Costs experienced for replacement and for production during replacement will vary depending upon skill of the personnel, the number of widgets in process at the time of replacement, and many other factors. While the cost of component replacement in the actual system cannot be known beforehand, there is some experience with similar components installed in previous systems. Out of 20 replacements of these components,

10 cost $10,000 each,

6 cost $15,000 each, and

4 cost $20,000 each.

If the present value of all other costs associated with the system (including the original installation of the component) is $50,000, and

experience with previous systems is considered representative, what is the expected NPV of costs for the system?

SOLUTION:

For this system,

$$NPV = \$50,000 + (E)(0.652)$$

where E is the expected cost of component replacement. The probability (relative frequency) that this cost will be \$10,000 is 10/20 or 0.5; the probability that it will be \$15,000 is 6/20 or 0.3; and the probability that it will be \$20,000 is 4/20 or 0.2. (Note that the probabilities of occurrence must sum to 1.0.) The expected value of the replacement cost is then computed from Equation VI-1 as:

$$\begin{aligned} E &= (0.5)(\$10,000) + (0.3)(\$15,000) + (0.2)(\$20,000) \\ &= \$5,000 + \$4,500 + \$4,000 \\ &= \$13,500 \end{aligned}$$

The expected NPV is then

$$\begin{aligned} NPV &= \$50,000 + (\$13,500)(0.652) \\ &= \$50,000 + \$8,802 \\ &= \$58,802 \end{aligned}$$

Example VI-9 is simplistic, but is merely intended to show how risk may be incorporated into the present value calculations of an economic analysis. In an actual case, many more than three discrete outcomes could be considered. In many cases, empirical data will be unavailable and probability estimates must be based upon limited information. While the use of a single expected value incorporates and describes risk, more information about risk may be desired for decision-making. The following subsection deals with more complete analysis of risk.

G. RISK ANALYSIS AND MONTE CARLO SIMULATION

Frequently, a decision-maker will desire information about the distribution of possible outcomes and their probabilities, in addition to the expected value of the outcome. For Example VI-9 of the previous subsection, the probability distribution of NPV outcomes is illustrated in the histogram of Figure VI-9. (Note that 0.5 x \$56,520 + 0.3 x \$59,780 + 0.2 x 63,040 = \$58,802, the expected value.)

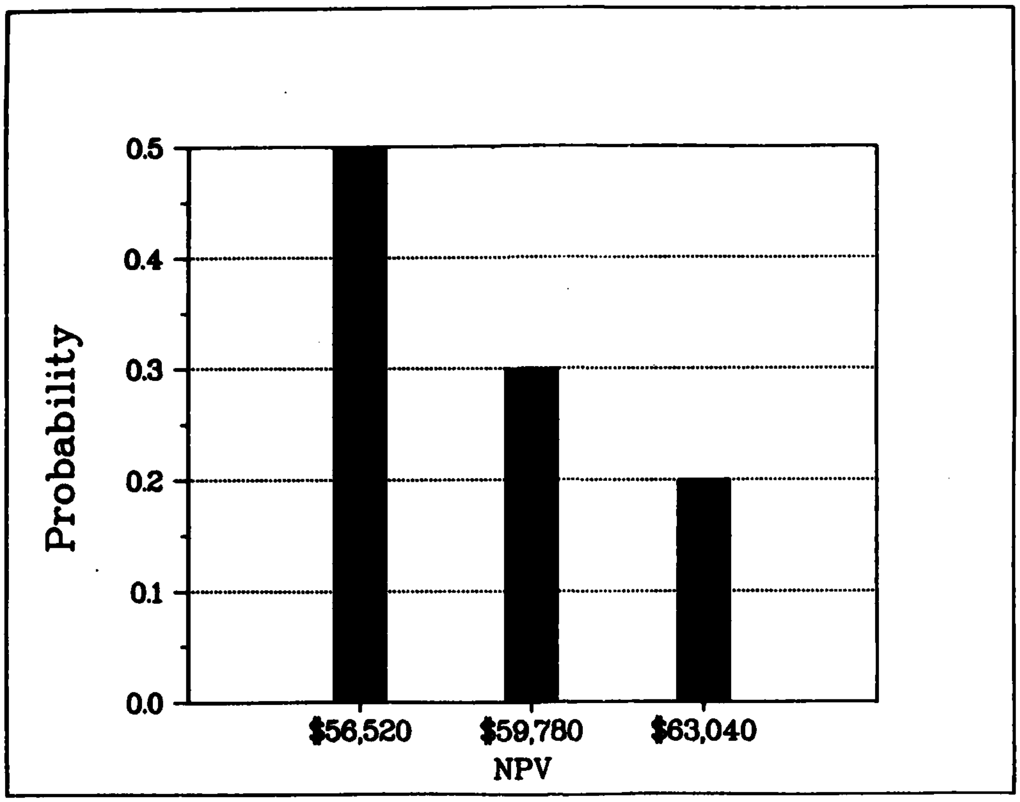


FIGURE VI-9

By developing the outcome probability distribution for each alternative under consideration, it is possible to portray the risk involved in each alternative and to compare the relative riskiness of the alternatives. In the case shown in Figure VI-9, developing the distribution was simple because only one probabilistic factor was involved. However, the analyst typically must deal with situations in which almost all of the variables have associated probability distributions.

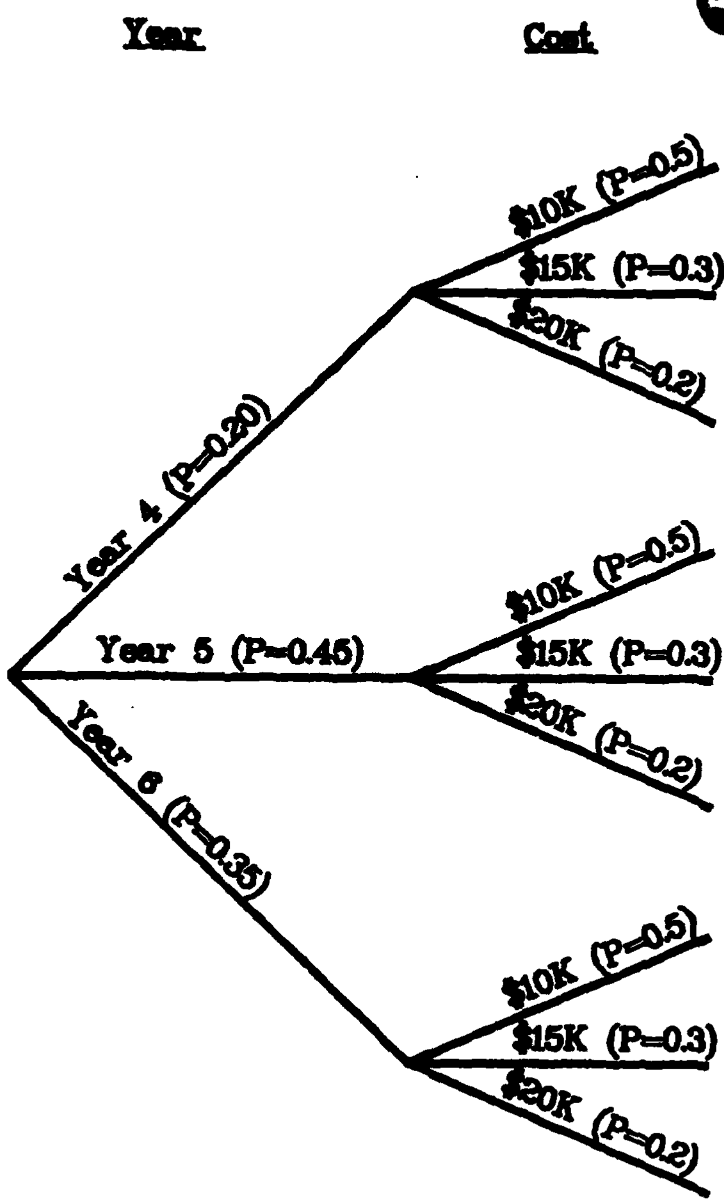
EXAMPLE VI-10: Suppose that in Example VI-9 of the previous subsection it is not certain that the component replacement will occur in Project Year 5, but rather that there is a 0.20 probability that it will occur in Project Year 4, a 0.45 probability that it will occur in Project Year 5, and a 0.35 probability that it will occur in Project Year 6. Further assume that the cost to replace the component (in base year constant dollars) is independent of the project year in which it occurs.

DISCUSSION: Since year of replacement and replacement cost are indpendent of each other, the probability of any particular combination of replacement year and replacement cost can be computed by multiplying the individual probabilities. One way to array the data for clarity and convenience in calculating the expected value and generating the probability distribution of outcomes is by a tree diagram such as that shown in Figure VI-10, which illustrates the nine possible outcome combinations of replacement years and replacement costs.

It is apparent that as the number of probabilistic variables becomes greater and as the number of values that each variable can assume becomes greater, the techniques discussed in the above examples become more unwieldy and burdensome.

It is usually impractical and economically infeasible to perform numerous experiments to gain experience from real world situations. However, performing experiments on a model of the real world can be done through the process of simulation. For risk analysis, the technique of Monte Carlo simulation is usually employed.

To perform a Monte Carlo simulation, it is necessary to have a set of random numbers, such as those shown in Table VI-2. By choosing probabilistic variable values based on these numbers, numerous trials may be simulated to develop an NPV distribution as in Example VI-11.



Probability	Outcome
0.100	NPV = $50K + $10K (0.717) = $57,170
0.060	NPV = $50K + $15K (0.717) = $60,760
0.040	NPV = $50K + $20K (0.717) = $65,850
0.225	NPV = $50K + $10K (0.652) = $56,520
0.135	NPV = $50K + $15K (0.652) = $59,780
0.090	NPV = $50K + $20K (0.652) = $63,040
0.175	NPV = $50K + $10K (0.592) = $55,920
0.105	NPV = $50K + $15K (0.592) = $58,880
0.070	NPV = $50K + $20K (0.592) = $61,840

FIGURE VI-10

TABLE VI-2

RANDOM NUMBERS

UNIFORMLY DISTRIBUTED BETWEEN ZERO AND ONE

.975078	.659518	.181406	.152768
.283958	.328833	.417378	.544767
.512201	.170302	.411998	.939272
.927648	.112442	.325820	.942946
.725291	.865235	.663791	.195627
.199643	.437218	.826516	.024134
.706160	.019756	.763094	.400762
.536728	.613510	.850510	.581468
.834217	.772092	.124594	.798741
.671094	.837898	.987540	.384159
.417096	.045141	.516985	.695639
.520970	.865065	.501659	.224368
.831275	.968344	.328587	.256421
.581244	.179677	.846862	.464077
.162709	.799559	.332974	.801810
.814090	.668254	.682709	.081972
.347447	.346938	.954601	.605167
.039592	.791046	.389954	.220309
.812263	.890798	.034425	.189366
.826367	.253911	.086166	.231795
.615267	.605503	.095533	.123665
.882195	.180185	.141354	.226462
.944640	.782560	.193596	.118540
.968870	.746361	.758340	.832789
.171677	.534959	.664667	.173333
.058054	.788328	.207482	.149942
.032314	.844410	.775632	.054095
.343896	.576517	.364043	.995601
.697222	.222922	.062533	.368905
.650629	.583632	.646129	.624085
.929354	.959358	.391961	.717539
.777586	.207666	.247724	.617350
.474577	.291315	.476697	.238349
.139820	.693784	.904319	.181860
.952289	.076991	.891342	.655135
.908735	.556190	.158531	.945471
.246051	.967067	.587937	.824023
.652703	.500010	.125731	.254297
.394209	.076579	.911591	.780336

EXAMPLE VI-11: A Monte Carlo simulation may be performed for the problem of the previous example as follows:

1. Values for the variables may be chosen based upon the random numbers by setting intervals in proportion to the probabilities, associating the respective values with those intervals, and then selecting a particular value when a random number falls within a particular interval. (Note that the random numbers in Table VI-2 are in the interval zero to one.)

For the year of component replacement, one might select:

Year 4 (P = 0.2) when the random number is in the interval 0.0 to 0.2;

Year 5 (P = 0.45) when the random number is greater than 0.2 and less than or equal to 0.65;

Year 6 (P = 0.35) when the random number is greater than 0.65 and less than or equal to 1.0.

Thus, for any simulated case, a replacement year is selected based on a random number; since the intervals are in proportion to the probabilities, the distribution of a large number of simulated cases will approximate the assumed probability distribution.

Similarly, for the cost component replacement the next random number might be used to select:

$10,000 replacement cost (P = 0.5) when the random number is in the interval 0.0 to 0.5;

$15,000 replacement cost (P = 0.3) when the random number is greater than 0.5 and less than or equal to 0.8;

$20,000 replacement cost (P = 0.2) when the random number is greater than 0.8 and less than or equal to 1.0.

2. By using the selection rules develped above, many simulated cases can be performed as in Table VI-3. From these numerous cases, the expected NPV and the probability distribution of NPV can be derived.

TABLE VI-3

MONTE CARLO SIMULATION (EXAMPLE VI-11)

Case No.	Random Number	Repl. Year	Random Number	Repl. Cost ($)	Disc. Factor	Disc. Repl. Cost ($)	Total NPV ($)
1	.975078	6	.659518	15,000	0.592	8,880	58,880
2	.181406	4	.152768	10,000	0.717	7,170	57,170
3	.283958	5	.328833	10,000	0.652	6,520	56,520
4	.417378	5	.544767	15,000	0.652	9,780	59,780
5	.512201	5	.170302	10,000	0.652	6,520	56,520
6	.411998	5	.939272	20,000	0.652	13,040	63,040
7	.927648	6	.112442	10,000	0.592	5,920	55,920
8	.325820	5	.942946	20,000	0.652	13,040	63,040
9	.725291	6	.865235	20,000	0.592	11,840	61,840
10	.663791	6	.195627	10,000	0.592	5,920	55,920
11	.199643	4	.437218	10,000	0.717	7,170	57,170
12	.826516	6	.024134	10,000	0.592	5,920	55,920
13	.706160	6	.019756	10,000	0.592	5,920	55,920
14	.763094	6	.400762	10,000	0.592	5,920	55,920
15	.536728	5	.613510	15,000	0.652	9,780	59,780
16	.850510	6	.581468	15,000	0.592	8,880	58,880
17	.834217	6	.772092	15,000	0.592	8,880	58,880
18	.124594	4	.798741	15,000	0.717	10,755	60,755
19	.671094	6	.837898	20,000	0.592	11,840	61,840
20	.987540	6	.384159	10,000	0.592	5,920	55,920
21	.417096	5	.045141	10,000	0.652	6,520	56,520
22	.516985	5	.695639	15,000	0.652	9,780	59,780
23	.520970	5	.865065	20,000	0.652	13,040	63,040
24	.501659	5	.224368	10,000	0.652	6,520	56,520
25	.831275	6	.968344	20,000	0.592	11,840	61,840
26	.328587	5	.256421	10,000	0.652	6,520	56,520
27	.581244	5	.179677	10,000	0.652	6,520	56,520
28	.846862	6	.464077	10,000	0.592	5,920	55,920
29	.162709	4	.799559	15,000	0.717	10,755	60,755
30	.332974	5	.801810	20,000	0.652	13,040	63,040
31	.814090	6	.668254	15,000	0.592	8,880	58,880
32	.682709	6	.081972	10,000	0.592	5,920	55,920
33	.347447	5	.346938	10,000	0.652	6,520	56,520
34	.954601	6	.605167	15,000	0.592	8,880	58,880
35	.039592	4	.791046	15,000	0.717	10,755	60,755
36	.389954	5	.220309	10,000	0.652	6,520	56,520
37	.812263	6	.890798	20,000	0.592	11,840	61,840
38	.034425	4	.189366	10,000	0.717	7,170	57,170
39	.826367	6	.253911	10,000	0.592	5,920	55,920
40	.086166	4	.231795	10,000	0.717	7,170	57,170

Average simulated NPV is $58,491

Because the Monte Carlo risk analysis method involves numerous repetitions of a procedure, it is more appropriate to perform it on a computer than to accomplish it by manual computations, especially when more variables and more complicated distributions than those in Example VI-11 are used.

So far, the assumed probability distributions and the resulting NPV distribution that we have examined have all been discrete, that is, they consist of a set of distinct values. For some variables, it is more reasonable to assume a continuous distribution, that is, a distribution consisting of an infinite set of values on a continuum. In a continuous distribution, the probability of any particular exact value occurring is zero, so the graph of a continuous distribution shows probability density instead of probability. The probability that the variable will take on a value in any interval is the area under the density curve in that interval; the area under the total curve is, by definition, one. An example of a continuous distribution is shown in Figure VI-11. This is a probability density graph for a cost with an assumed normal (Gaussian) distribution, with a mean (i.e., expected value) of \$2,000, and a standard deviation (a measure of dispersion) of \$200. (Note that the area under the normal curve between the mean and one standard deviation above the mean is approximately one third of the area under the whole curve.)

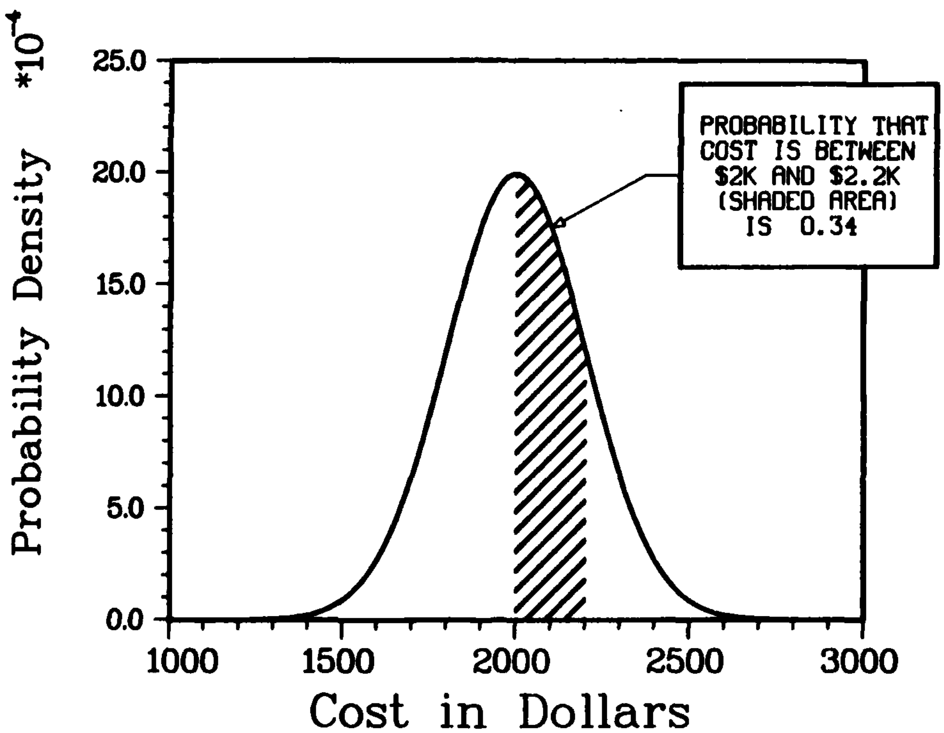


FIGURE VI-11

Once an NPV probability distribution has been developed for each alternative by Monte Carlo simulation, the results should be appropriately displayed for the decision-maker. How this information is used for decision-making will depend upon the decision-maker's aversion to risk. For example, in the comparison shown in Figure VI-12 below, Alternative A has an expected NPV cost that is lower than that of Alternative B, but it also has a wider range of possible outcomes; in fact, there is a measurable probability that Alternative A will cost more than the highest cost of Alternative B.

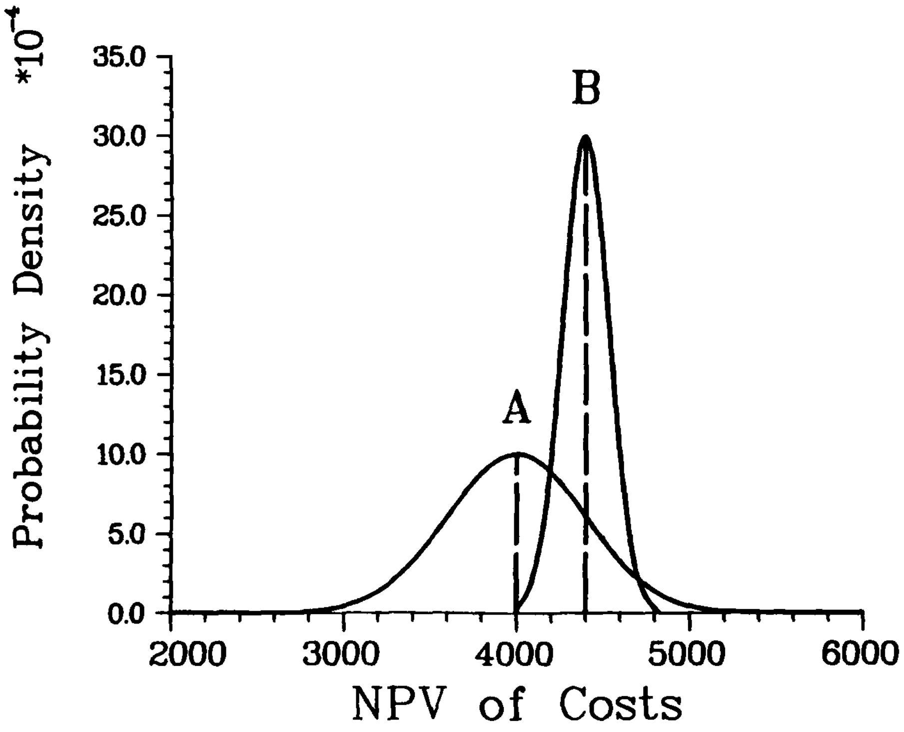


FIGURE VI-12

Another display technique for the results of a Monte Carlo risk analysis is to graph the cumulative probability distributions of the alternatives. The cumulative NPV probability distribution displays the probability that the NPV will be less than or equal to any particular amount. Figure VI-13 indicates that there is a 40% probability that the Alternative A NPV will be less than or equal to $3,900.

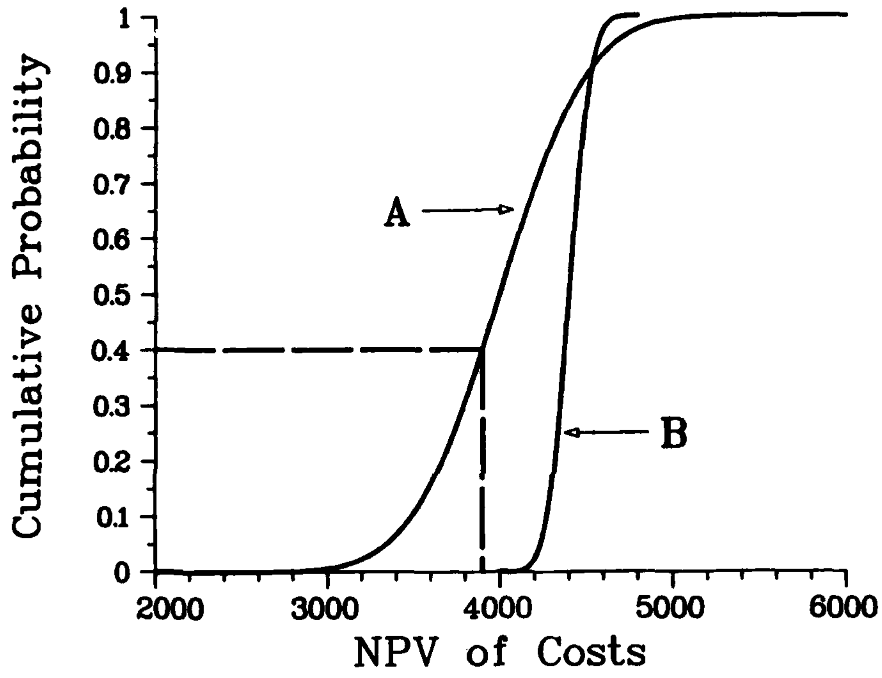


FIGURE VI-13

The narrative in this subsection is intended to acquaint the reader with basic concepts and convey the basic elements of a risk analysis. For in-depth information, the reader should refer to the reference works on probability, statistics, and risk analysis listed in Appendix H.

VII. TREATMENT OF INFLATION

A. INTRODUCTION

In the real world, cost estimation is complicated by a combination of two circumstances:

1. There is a time lag between cost estimation and actual expenditure.

2. Costs and prices change over time. When a period of a continuing rise in general price levels is meant, this condition is referred to as inflation. When a period of falling price levels is meant, it is referred to as deflation. (The term cost escalation is used to mean a rise in the price of a particular commodity or service.)

The problem caused by inflation is not simply that future acquisitions are likely to cost more than today's estimates; there is also uncertainty as to how much more they will cost. It is this uncertainty which so complicates financial planning, and thus economic analysis as well.

This section explores the nature of inflation-associated problems, outlines current policy guidance for addressing such problems in economic analysis, and develops analytical procedures consistent with this policy guidance. In practice, the treatment of inflation usually addresses two separate time periods:

1. The interval between the preparation time of the cost estimates and the zero point or base year of the analysis.

2. The project life of the analysis.

As will be seen, this fragmented approach is necessary because discount factors, which incorporate a 10% real opportunity cost of capital, are applied to costs during the project life.

B. MEASURING INFLATION AND COST ESCALATION

Changes in prices over time may be measured by a series of index numbers. An index number is a measure of relative value compared with a base figure for the same series. Most price indices consist of a number of components which are combined according to a set of weights. The price of each component is determined during each period. For example, a construction cost index might consist of various material, equipment, and labor components. The prices of these components would then be combined using weights which reflect the relative contribution of each component to total construction cost. The base period index value is usually set at 100.

Figure VII-1 illustrates the Engineering News-Record (ENR) Building Cost Index for each month in the period 1977-1979. The index prices constant quantities of structural steel, portland cement, lumber, and skilled labor. (Note that the index does not adjust for productivity changes, changes in competitive conditions, design changes, or qualitative changes -- accordingly, indices should be used with care.) The base year of the index is 1913. The ENR Building Index might be used by the analyst to escalate historical construction costs to constant dollars of the present year. (The ENR Building Cost Index was used to derive the 1980 constant dollar UEPH construction costs shown in Figure IV-1 of Subsection IV-H.)

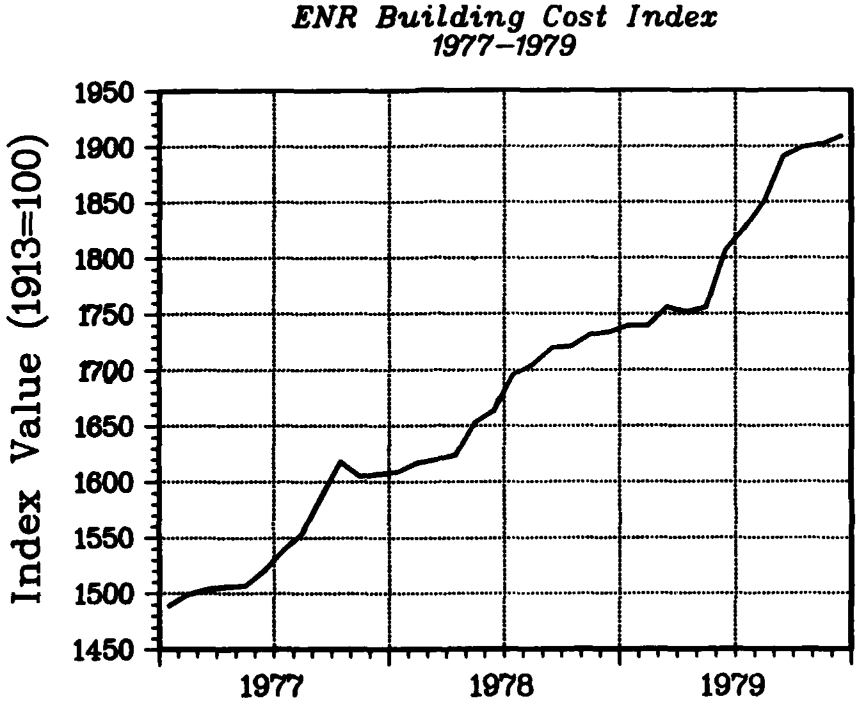


FIGURE VII-1

Figure VII-2 illustrates a different type of price index -- the Gross National Product (GNP) Implicit Price Deflator. The GNP is the market value of the output of all final goods and services produced by the nation's economy in a specified time period. The GNP Price Deflator is used to make comparisons of the GNP for different years; the index value is the weighted average of many price indices that relate to the components of GNP. The weights that are used to combine these indices are the relative expenditures in each component category in the current period. (Therefore, the weights are different for each period.) Because it is so comprehensive, the GNP Price Deflator is widely regarded as the best single measure of changes in the general price level of the U.S. Figure VII-2 shows how this index has changed

from 1929 on. (Note that the general price level dropped during the Great Depression of the 1930's -- i.e., during this period, the economy experienced deflation rather than inflation.)

GNP Implicit Price Deflator

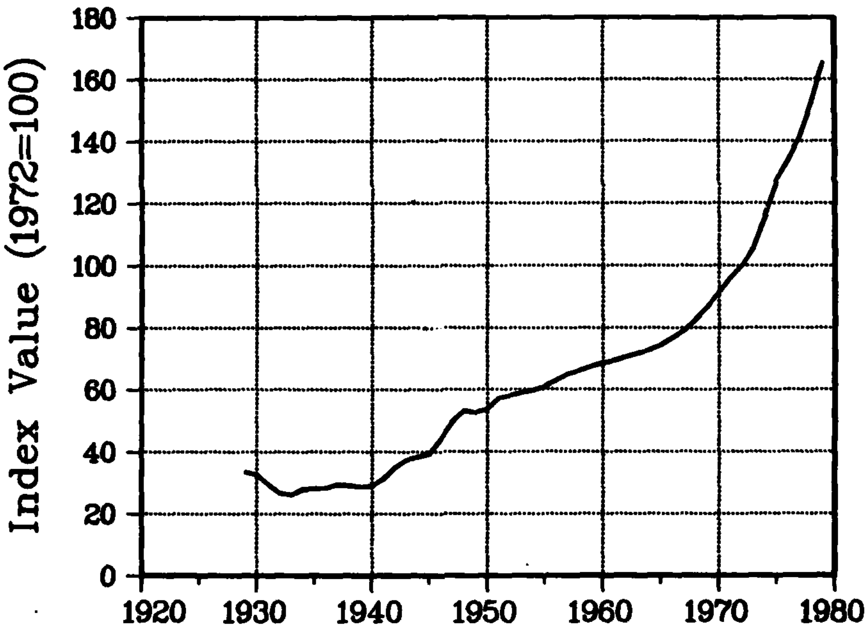


FIGURE VII-2

The most widely known index is probably the Consumer Price Index (CPI). It is usually changes in this index that are reported in the news media as changes in the "cost of living." The CPI represents prices paid by urban wage earners for a "market basket" of consumer items.

Many other indices are compiled and published by the U.S. Government and by private organizations for various purposes. Thus, indices are available for measuring both trends in escalation for specific types of costs and trends in the general purchasing power of the dollar.

C. THE PERIOD BETWEEN THE ESTIMATE DATE AND THE ANALYSIS ZERO POINT

The expectation that costs will escalate applies not only to the near future, but to the indefinite future as well. In economic analysis, however, treatment of the two situations (near-term vs. long-term future) differs.

First a definition of terms is in order:

* For purposes of this discussion, preliminary period means the period from the estimate date to the analysis base year (zero point) inclusive. It is during this period that the project or program must be approved and funding must be authorized and appropriated, all prior to the initial investment expenditure. Escalation from past or present estimates to the base year is discussed in this subsection.

* The long term future extends beyond the analysis base year through the final project year. It includes any necessary lead time period (e.g., for a facility, the time between initial investment expenditure and the date of beneficial occupancy) and the economic life immediately following. The lead time and economic life together make up the project life, during which are incurred all recurring annual costs and any one-time cash flows after the base year. Escalation of these costs is discussed in Subsection VII-D.

The time periods defined above are diagrammed in the illustrative time profile of Figure VII-3. The figure shows a preliminary period of 4 years, a project lead time of 2 years (Project Years 1 and 2), and an economic life of 25 years (Project Years 3 through 27).

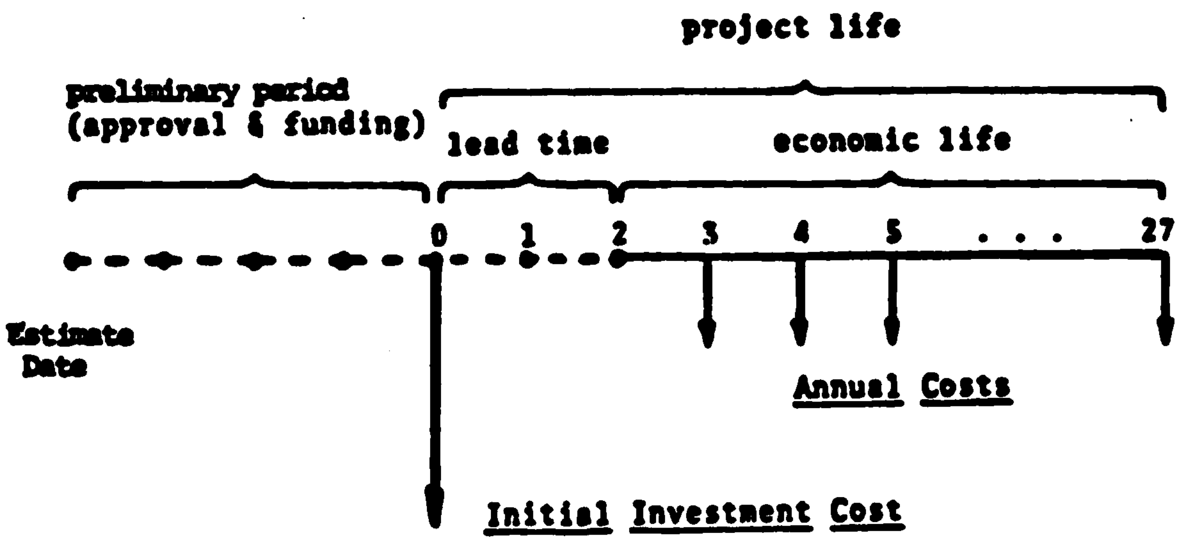


FIGURE VII-3

The first task confronting the analyst in the treatment of inflation is the escalation of costs from the time of their estimation to the base year. For most economic analyses, the base year used coincides with the time of initial investment. Choosing the initial investment year to be the base year has the useful property that the investment cost estimate is equal to the budget request for that investment. They are equal because both are stated in terms of budget year constant dollars. (However, for analyses of certain energy conservation proposals, use of the analysis year as the base year has been directed for the Federal Energy Management Program (FEMP). Refer to Appendix B.)

For proposed military construction projects, the lag between preparation of the economic analysis and obligation of initial funding can range up to three years or more. Over such periods the question is not whether costs will escalate, but how much. (Furthermore, the analyst may be obliged to use historical cost information in the economic analysis. Estimates derived from historical information must be adjusted for any escalation that has already occurred, as well as for near-term future escalation.)

Attempts are made to answer the how much? question at various levels. The Office of the Secretary of Defense, Program Analysis and Evaluation (OSD, PA&E) regularly disseminates cost escalation projections for military construction and family housing; research, test, development, and evaluation (RDT&E); and other major areas of procurement. Within the Department of the Navy, this information is forwarded to all major commands by the Office of the Chief of Naval Operations (CNO). Its main intended purpose is to provide escalation guidance for preparation of the Program Objectives Memorandum (POM). The Naval Facilities Engineering Command Headquarters periodically disseminates construction cost escalation guidance to its Engineering Field Divisions (EFD's). The EFD's themselves track developments in construction costs within their respective geographical areas.

Current general trends in construction costs are also monitored by such sources as the Engineering News-Record, which (as noted in the previous subsection) publishes cost indices compiled on a monthly basis, and by Construction Review, published by the Department of Commerce.

Officially disseminated cost projections should not be construed as anything more than a guideline. Where available, specific local data may be used to establish a more realistic cost model. All sources should of course be explictly documented (see Subsection IV-J).

Projections of cost escalation may take the form either of percentages or cost indices. Table VII-1 shows some hypothetical projections. The examples following illustrate how to treat each case.

TABLE VII-1

HYPOTHETICAL NEAR TERM ESCALATION GUIDANCE

(19x1-19x4 Historical, 19x4-19x8 Projected)

Escalation Indices

FY	RDT&E	MILCON	O&M	Ships
19x1	78.65	77.15	78.22	78.23
19x2	85.41	84.56	85.34	85.89
19x3	92.42	92.34	92.25	92.94
19x4	100.00	100.00	100.00	100.00
19x5	107.70	107.60	107.80	107.30
19x6	115.45	115.35	115.35	116.10
19x7	122.96	122.96	122.84	124.11
19x8	129.72	130.34	129.60	132.67

Annual Rates (Percentages)

19x1-19x2	8.6	9.6	9.1	9.8
19x2-19x3	8.2	9.2	8.1	8.2
19x3-19x4	8.2	8.3	8.4	7.6
19x4-19x5	7.7	7.6	7.8	7.3
19x5-19x6	7.2	7.2	7.0	8.2
19x6-19x7	6.5	6.6	6.5	6.9
19x7-19x8	5.5	6.0	5.5	6.9

EXAMPLE VII-1: Take FY 19x4 to be the present. Given the cost escalation percentage projections shown in Table VII-1, escalate a construction cost estimate of $1.20M (FY 19x4 dollars) to the amount we would expect to have to fund in FY 19x8.

SOLUTION: By means of the Military Construction escalation percentage projections, the FY 19x4 estimate must be escalated 7.6% to produce a FY 19x5 estimate, which in turn must be escalated 7.2% to yield a FY 19x6 estimate, and so on. The final estimate is

$$\text{FY 19x8 estimate} = (\$1.20\text{M})(1.076)(1.072)(1.066)(1.06)$$

$$= \$1.56\text{M}$$

The calculation in Example VII-1 yields the escalated amount that is actually expected to occur. The simplistic approach of adding each year's percentage escalation to produce an aggregate four year percentage escalation (27.4% = 7.6% + 7.2% + 6.6% + 6%), understates the final result as the following calculation shows:

$$(\$1.20M)(1.274) = \$1.53M$$

The higher the yearly escalation figures or the longer the overall escalation period, the greater the distortion introduced by adding each year's percentage escalation to produce an aggregate figure. (This effect notwithstanding, when monthly escalation projections are given as percentages, they are usually understood to be summable to yearly projections. Thus, 1%/month is equivalent to 12%/year).

In the special case for which the future escalation rate is expected to be a constant fraction e per year, a cost estimate C_0 is escalated for n years as follows:

$$C_n = C_0(1+e)^n \qquad \ldots \text{(VII-1)}$$

EXAMPLE VII-2: Using the Military Construction index of Table VII-1, escalate a FY 19x4 construction cost estimate of $1.20M to the anticipated amount which will actually have to be paid in FY 19x7.

DISCUSSION: As explained in Subsection VII-B, price or cost indices are numbers which are proportional to prices (or costs) in the stated periods. The Military Construction index suggests that a structure which costs $10,000 to build in FY 19x4 will cost $12,296 to build in FY 19x7. The difference is due solely to expected construction cost escalation between FY 19x4 and FY 19x7.

SOLUTION: The FY 19x7 construction cost estimate is:

$$\$1.20M \times \frac{122.96}{100.00} = \$1.48M$$

The index values of 122.96 for FY 19x7 and 100.00 for FY 19x4 correspond to the percentage projections of Table VII-1, since:

$$(100)(1.076)(1.072)(1.066) = 122.96$$

The following example illustrates the use of an index to escalate an estimate from yesteryear's dollars to today's dollars.

EXAMPLE VII-3: Again taking FY 19x4 as the present, escalate a ship acquisition estimate of $250M in FY 19x2 dollars to the current budget year.

SOLUTION: Using the Ships index of Table VII-1, we have:

$$\$250M \times \frac{100.00}{85.89} = \$291.1M$$

The techniques described and illustrated above must be applied to recurring annual costs as well as to investment costs for the period between the estimate date and the analysis base year. An annual cost estimate made in terms of present day prices should be escalated to the expected cost as of the analysis zero point. All cost estimates must be escalated to constant dollars of the analysis base year. The escalation of costs within the project life is a different matter, however, to be addressed in the next subsection.

D. TREATMENT OF INFLATION DURING THE PROJECT LIFE

The straightforward escalation techniques described in Subsection VII-C cannot be directly applied to costs during the project life. The reasons are twofold:

1. Inflation guidance of the type cited in Subsection VII-C typically extends only a few years into the future. Within the hierarchy of OMB/DOD/Navy economic analysis instructions, there are no inflation rates prescribed for the 15, 20, or 25 year periods common in economic analysis. Indeed, there is no reliable basis for quantitative forecasting of price levels that far into the future.

2. Costs incurred during the project life of an economic analysis (i.e., from Project Year 1 on) are discounted to their "present value" (i.e., Time Zero) equivalents. THE STANDARD 10% DISCOUNT FACTORS AUTOMATICALLY ADJUST FOR THE GENERAL INFLATION RATE DURING THE PERIOD FOR WHICH THEY ARE APPLIED BECAUSE THE 10% DISCOUNT RATE IS A REAL (I.E., ADJUSTED FOR INFLATION) RATE.

EXAMPLE VII-4: Consider a proposed project with the costs shown in Figure VII-4. The $1M and $50K are costs estimated in terms of Time Zero prices.

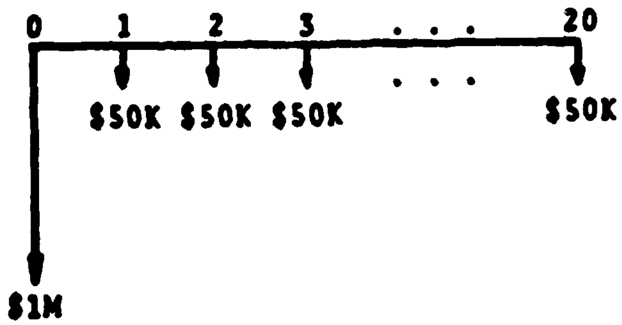


FIGURE VII-4

Because of anticipated inflation during Project Years 1-20, the total expected budgetary outlay is NOT $1M + 20·$50K = $2M; it will be more. But when the total present value cost is calculated,

$$\text{TPV Cost} = \$1M + \$50K(8.933) = \$1.447M,$$

inflation is implicitly incorporated into the final result. For example, the 8th year (Table A, Appendix E) discount factor, 0.489, automatically escalates the $50K Zero Point budgetary estimate to the actual expected cost in Project Year 8 before discounting it back to the Time Zero present value equivalent. The same type of implicit escalation is accomplished by each Table A factor as it is applied to its respective cost. Since cumulative (Table B) discount factors are just accumulated sums of single amount (Table A) factors, they automatically adjust for inflation also. The 20 year Table B factor 8.933 inflates each annual cost at the same time that it discounts the entire 20 year cost stream.

To summarize, the stream of constant annual costs (i.e., constant dollar constant annual costs) shown in Figure VII-4 does not represent expected budgetary outlays during the project years. The effects of inflation are included in the analysis only when discount factors are applied to these costs, which have been estimated in terms of Zero Point prices. In effect, budgetary reality is sacrificed in the cash flow diagram so that the present value cost comparison in the economic analysis will be realistic. This is appropriate, since the cash flow diagram is a tool for preparation of economic analyses rather than budget requests.

REMARKS:

1. The pattern of annual costs can be non-uniform for reasons other than inflation. Maintenance costs may increase with age, for example, or periodic future investment outlays may be necessary for repair or replacement of physical assets, or a "learning curve" effect

may reduce costs for a new type of operation, or growth in a requirement for services may increase real costs over time. To the extent that these circumstances can be foreseen and justified, they should be reflected in basic annual cost estimates and cash flow diagrams.

2. The 10% discount factors adjust only for the general inflation rate. If an annual cost (or cost component) is not expected to escalate at or near the general inflation rate, a special adjustment for escalation (described later in this subsection) may be necessary.

3. If long term general price trends cannot be predicted with any significant degree of reliability, how is it that the 10% discount factors adjust base year cost estimates for the general rate of inflation? The answer to this question is tied to the supposition that the real rate of return on private sector investment capital is relatively stable in the long run. As pointed out in Subsection III-C, it is the rate of return on private sector investment capital which the 10% Government discount rate attempts to measure. The term "real rate of return" means that the decreasing purchasing power of money (due to inflation) has been taken into account. If in fact such a stability exists, then there is a reasonable assurance that the discount factors do adjust for general price increases, even though future general inflation rates are not specifically known. A more complete explanation is difficult without considering the derivation of the offically prescribed 10% discount rate.

An important contribution to the choice of a 10% discount rate was the paper "Measuring the Opportunity Cost of Government Investment," IDA Research Paper P-490, March, 1969, by J.A. Stockfisch. The paper's working premise is that the rate of return (i.e., "discount rate") appropriate to the economic evaluation of Government investment proposals should equal the rate of return generated by private, physical investment. (See also Subsection III-C.)

The main effort of the Stockfisch paper was directed toward estimating the private sector rate of return on investment capital. Using data from the period 1949-65, Stockfisch examined a cross-section of major U.S. industries. Separate rates of return were derived for three general areas: (1) corporate manufacturing, (2) public utilities, and (3) the noncorporate sector. An overall composite rate of return was then determined by weighting each of these three rates in proportion to its relative importance and computing the weighted average of the three -- the result was 12%.

The 12% figure, however, represents a nominal rate of return, i.e., a rate unadjusted for inflation. The business financial records from which the 12% rate was derived were kept in terms of historical prices, so that an inflationary bias was implicitly introduced. Because price increases intervene between the purchase of capital equipment and the realization of a monetary return from that equipment, a return calculated on the basis of accounting book records is artificially high.

To correct for this overstatement, Stockfisch netted 1.6%, the average annual increase in the Personal Consumption Expenditure Deflator Index during the period 1949-1965, against the nominal return of 12%, to obtain a 10.4% estimated real rate of return on private sector investment capital. The 10% rate subsequently prescribed for the evaluation of Government investment decisions is similarly to be construed as a real rate of return.

The following example, although admittedly simplistic, might help clarify the distinction between nominal and real rates of return.

EXAMPLE VII-5: A corporation is contemplating a \$100K investment for a one-year period. If

a. the investment is to be made today;

b. the firm seeks a 10% real rate of return on the investment; and

c. the expected inflation rate during the next year is 5%;

what total return should the corporation seek in one year's time?

SOLUTION: If the 5% inflation materializes, the corporation would need a \$105K return just to break even in terms of purchasing power (i.e., it will take \$105K one year from today to buy what \$100K will buy today). A 10% rate of return on this breakeven amount is

$$\$105K \times .10 = \$10.5K.$$

The total return sought by the firm at the end of one year is

$$\$105K + \$10.5K = \$115.5K.$$

In view of the 5% inflation, this represents a 10% real rate of return on the \$100K investment. But the nominal rate of return is 15.5%, since

$$\frac{\$115.5K - \$100K}{\$100K} = 15.5\%.$$

(This is the rate which would be reflected by the corporation's financial records.)

If the 12% nominal rate of return and 1.6% inflation figure derived in the Stockfisch paper are accepted as reliable long term trend indicators, then applying 10.4% discount factors to constant dollar costs is essentially equivalent to applying 12% discount factors to "current dollar" costs obtained by inflating base year annual cost estimates 1.6%/year. This is true because of the approximate equality

$$\frac{1}{(1.104)^n} = \left[\frac{1}{1.104}\right]^n \approx \left[\frac{1.016}{1.12}\right]^n = \frac{(1.016)^n}{(1.12)^n}.$$

(1/1.04 = 0.905797 and 1.016/1.12 = 0.907143, for a difference of approximately 0.15%. This difference increases as successively higher powers of these fractions are taken (for annual costs incurred during the out-years), but even for n = 25 the approximation is still a good one:

$$\left[\frac{1}{1.104}\right]^{25} = 0.084289, \qquad \left[\frac{1.016}{1.12}\right]^{25} = 0.087477,$$

yielding a percentage difference of only 3.64%. The uncertainty in the cost estimate itself, expressed as a percentage, will be higher in almost all cases.)

By the same rationale, the 10% Government discount rate adjusts constant dollar annual costs for the general inflation rate. The objection might be raised that more recent data would substantially alter the 12% and 1.6% Stockfisch estimates for the nominal rate of private sector investment return and the average annual rate of inflation, respectively. But if 10% is accepted as the real rate of return on private investment (as specified by OMB Circular No. A-94 (Revised) and DODINST 7041.3), the absolute magnitudes of the inflation rate and the nominal rate of return are not important in and of themselves. So long as the two rates vary in such a way that there is an approximate 10% difference between them (as there is between 1.05 and 1.155 in Example VII-5), use of the standard 10% discount factors automatically introduces the effect of the general inflation rate. (Long term parallel movements of inflation rates and nominal rates of return are suggested by a characteristic peaking of interest rates during periods of high inflation. There is a positive correlation between the prevailing interest rate and the nominal rate of return sought for corporate investment, since the interest rate represents the cost of money borrowed to finance business ventures.)

The foregoing discussion notwithstanding, the standard 10% discount factors do not assess the total impact of escalation in all cases. The expectation that a particular cost element will undergo anomalous long term escalation behavior can raise legitimate concern about the outcome of an economic analysis.

Department of Defense policy regarding the treatment of inflation in economic analyses, as promulgated by DODINST 7041.3, requires a two phase approach:

1. The analysis should be performed first in terms of constant dollars. I.e., all estimates of costs and monetary benefits during the project life should be made in terms of base year prices.

2. If inflation is deemed important to the conclusion of the study, a second computation should be made in terms of escalated annual costs and monetary benefits.

The requirement to perform a baseline analysis in contant dollars promotes consistency among comparative economic studies done within the Department of Defense. Since the standard 10% discount factors implicitly escalate constant dollar cost estimates at the general inflation rate, the baseline comparison should suffice in many cases. Consequently, specific assumptions regarding irregular inflationary behavior over the long term should not be made lightly.

If a second, inflated-dollar comparison is nonetheless considered appropriate, only a differential escalation rate (i.e., the expected difference between the average long term general rate and the long term rate for this particular cost or cost element) should be applied in the escalation of the base year annual cost estimate. It must be remembered that an escalation at the general inflation rate is automatically introduced when discount factors are applied.

The following simple example shows the connection between differential escalation rates, total inflation rates, the real rate of return on private sector investment, and the nominal rate of return on private sector investment.

EXAMPLE VII-6: Suppose that the expected general inflation rate is 5%/year and the expected nominal rate of return on private-sector investment capital is 15%/year (for an effective real rate of approximately 10%/year) over the economic life of an analysis. If a cost element is expected to escalate at, say, 8%/year, then present values may be calculated by discounting at 10% and inflating at the differential rate of 3%. This is essentially equivalent to the generic approach of discounting at 15% and inflating at 8%, because of the approximation

$$\frac{(1.03)^n}{(1.1)^n} = \left[\frac{1.03}{1.1}\right]^n \approx \left[\frac{1.08}{1.15}\right]^n = \frac{(1.08)^n}{(1.15)^n}$$

It has been pointed out previously that year to year price index projections are generally not available for future periods as long as 15, 20, or 25 years. If a supplementary, escalated analysis is to be performed, choice of a differential escalation rate is at best a process of educated guesswork. Clues which will aid in this guesswork may be found by examining historical trends.

EXAMPLE VII-7: Suppose that 19x6 is the present and that research has uncovered the following index values:

Year	General Inflation Index	Widget Index
19x0	100.00	135.10
19x5	127.63	189.48

What uniform annual rates are equivalent to the observed increases in these indices for the period 19x0-19x5? What was the differential escalation rate for widgets during this period?

SOLUTION: The index values are related to the equivalent annual rate e by substitution in equation VII-1:

$$(19\text{x}0 \text{ value})(1 + e)^5 = (19\text{x}5 \text{ value})$$

The above equation can be solved for e in order to find the equivalent annual rate of increase. One way to do this is by trial-and-error. However, the analyst who is familiar with the use of logarithms (and has an electronic calculator or tables of logarithms handy) can solve the equation for e directly. For the general inflation rate:

$$(100.00)(1 + e)^5 = 127.63$$

Rearranging terms, we have:

$$(1 + e)^5 = \frac{127.63}{100.00} = 1.2763$$

Taking the logarithm of both sides of the equation leads to:

$$\log(1 + e)^5 = \log 1.2763$$

Applying the rule $\log a^b = b \log a$ to the left side of the equation yields:

$$5 \log (1 + e) = \log 1.2763$$

Dividing both sides of the equation by 5, we have:

$$\log (1 + e) = \frac{\log 1.2763}{5}$$

Taking the antilogarithm of each side of the equation yields:

$$(1 + e) = \text{Antilog}\left[\frac{\log 1.2763}{5}\right]$$

Solving for e, we have:

$$e = \text{Antilog}\left[\frac{\log 1.2763}{5}\right] - 1$$
$$= .05$$

The uniform annual general inflation rate has been 5%. By using the Widget Index values in the equation, the equivalent uniform annual rate of increase for widget costs is found to be 7% for the five year period. Therefore the annual differential escalation rate for widget costs was 7% - 5% = 2% for the period 19x0 to 19x5.

Of course, the analyst should examine year to year rates of change as well as those for longer periods. Other periods could also be examined. If the analyst determines that the conditions causing the historic differential escalation of widget costs are likely to continue, the assumption might be made that widget costs will continue to escalate at about 2% above the general inflation rate.

Differential escalation is usually incorporated in economic analysis in one of two ways:

1. A single differential escalation rate is applied throughout the project life. This approach provides computational expediency. The differential escalation rate may be provided by official guidance or it may be assumed based upon research.

2. Several differential escalation rates are applied during the project life and each rate is associated with a specific set of years. This approach is used for the energy cost projections performed by the Energy Information Administration (EIA) of the Department of Energy (DOE).

The remainder of this section applies to the use of the same differential escalation rate for each year of the project life. Use of EIA differential escalation projections is described in Appendix B.

Once a differential escalation rate has been selected, the (differential) escalation and discounting of project costs may be done in either order, since both operations are multiplicative. The tables of Appendix F, however, allow both processes to be accomplished in a single operation. Appendix F contains three pages of single amount differential escalation-discount factors (analogous to Table A, Appendix E), followed by three pages of cumulative uniform series differential escalation-discount factors (analogous to Table B, Appendix E). There are factors for the differential escalation rates -5%, -4%, ..., -1%, 1%, 2%, ..., 10%. In addition to escalating at the indicated differential rate, these factors simultaneously discount at the 10% discount rate. In using these factors, the analyst (and reviewer) should keep in mind the two functions which they perform: first, escalating the cost(s) to a level expected for that point in time, and second, discounting cost(s) to take account of the time value of money.

In Type II economic analyses, it is often possible to avoid arbitrary choice of a differential escalation rate by taking an uncertainty analysis approach. The following example illustrates this technique, along with use of the tables in Appendix F.

EXAMPLE VII-8: A facility is to be built at Naval Weapons Station (NWS) Somewhere. The possibility of incorporating various features into the design is being analyzed. Under consideration are the following design alternatives: A, B, and C.

In the data below, only costs which will vary between design alternatives have been included.

Economic Life. . . . . 25 years

Investment Costs (Year 0)

Alternative A	$52,300
Alternative B	$65,900
Alternative C	$44,300

Annual Recurring Costs (Years 1-25)

Alternative A	$5,718
Alternative B	$4,982
Alternative C	$7,029

NOTE: All costs are estimated in terms of base year dollars.

With this data, (a) perform a baseline analysis, using standard 10% discount factors, to determine the (present value) least cost design option, and (b) determine for which positive differential escalation rate(s) your decision in (a) would change.

SOLUTION: Net present value (NPV) calculations are shown for differential escalation rates of 0%, 3%, 6%, and 9%. (It is not considered likely that these particular costs will escalate less rapidly than general price levels; therefore, no negative differential rates are used.)

BASELINE COMPARISON (no differential escalation assumed):

NPV(A) = \$52.3K(1.000) + \$5.718K(9.524) = \$106.8K
NPV(B) = \$65.9K(1.000) + \$4.982K(9.524) = \$113.3K
NPV(C) = \$44.3K(1.000) + \$7.029K(9.524) = \$111.2K

(factors taken from Table B, Appendix E)

3% EXTRA ESCALATION:

NPV(A) = \$52.3K(1.000) + \$5.718K(12.270) = \$122.5K
NPV(B) = \$65.9K(1.000) + \$4.982K(12.270) = \$127.0K
NPV(C) = \$44.3K(1.000) + \$7.029K(12.270) = \$130.5K

(factors taken from Appendix F, Page F-6)

6% EXTRA ESCALATION:

NPV(A) = \$52.3K(1.000) + \$5.718K(16.303) = \$145.5K
NPV(B) = \$65.9K(1.000) + \$4.982K(16.303) = \$147.1K
NPV(C) = \$44.3K(1.000) + \$7.029K(16.303) = \$158.9K

(factors taken from Appendix F, Page F-7)

9% EXTRA ESCALATION:

NPV(A) = \$52.3K(1.000) + \$5.718K(22.351) = \$180.1K
NPV(B) = \$65.9K(1.000) + \$4.982K(22.351) = \$177.3K
NPV(C) = \$44.3K(1.000) + \$7.029K(22.351) = \$201.4K

(factors taken from Appendix F, Page F-7)

On the basis of these results, life cycle cost curves are plotted in Figure VII-5 as functions of the differential escalation rate.

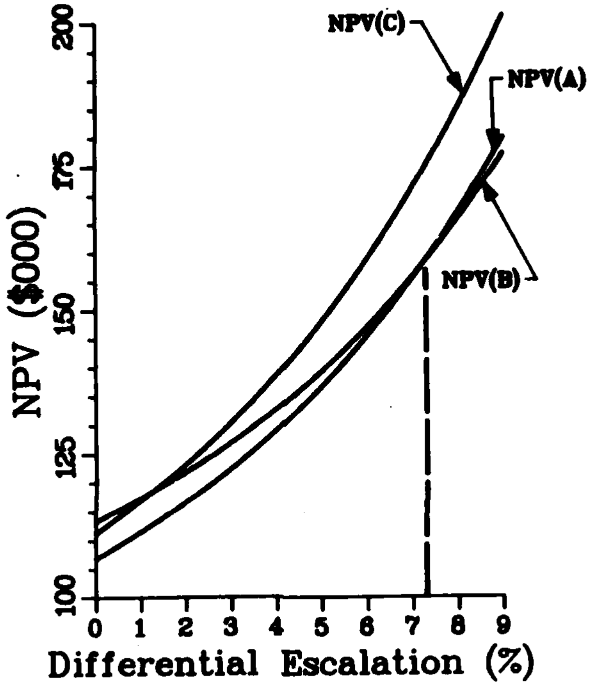


FIGURE VII-5

In the baseline comparison (no extra escalation in recurring costs assumed), Alternative A has the least (discounted) life cycle cost, \$106.8K. As can be seen from Figure VII-5, the NPV(A) curve lies below the NPV(C) curve for all positive differential escalation rates; in this range, Alternative A economically dominates Alternative C. However, there is a crossover between the NPV(A) and the NPV(B) curves somewhere in the 7-8% differential escalation range. The magnitude of the breakeven differential escalation rate may be estimated from the following calculation:

NPV(A) = NPV(B) yields $\$52.3K + \$5.718K \cdot B_{25} = \$65.9K + \$4.982K \cdot B_{25}$

(where B_{25} = 25 year cumulative uniform series factor for the breakeven differential escalation rate)

Solving the latter equation for B_{25} yields $B_{25} = 18.478$. Reference to Appendix F shows that this result lies between the 25 year factors for differential escalation rates of 7% and 8%, which are 18.049 and 20.050, respectively. Linearly interpolating $B_{25} = 18.478$ between these two values, we obtain an estimate of 7.2% for the breakeven differential escalation rate. This is in good agreement with Figure VII-5.

Although the factors of Appendix F (and, in fact, Appendix E) accomplish the operations of inflating and discounting simultaneously, there is a clear conceptual distinction between the two. Costs are discounted because, basically, money commands a price (or rate of return) for its use. This is a universal attribute of money, one which would exist even if there were no such thing as inflation.

In practice, inflating and discounting of costs work at cross purposes. Discount factors reduce future cash flows to present value equivalents in spite of inflation, not because of it. The higher the rate at which a cost is escalated, the more the impact of discounting is offset. This trend is shown by the tables in Appendix F: for any given project year the escalated discount factor (single amount or cumulative) is larger, the higher the escalation rate. For a differential escalation rate of 10%, discounting at 10% is completely negated.

If annual costs are expected to escalate more rapidly than general prices in the long term, then, in an economic analysis, the alternative with the higher annual cost is more vulnerable to escalation. This vulnerability is clearly demonstrated in Figure VII-5. Design Alternative C, with the highest annual cost, is decidedly less cost effective than the other two at high escalation rates. Design Alternative B, which is shown to be least cost effective in the baseline comparison, actually becomes the most economically attractive choice if the differential escalation rate is sufficiently high.

The analysis of Example VII-8 would properly be interpreted by management as follows: Alternative C, though it has the least initial investment cost ($44.3K), is never favored from a discounted life cycle cost standpoint. If annual costs are expected to escalate less than 5%/year above general price increase rates, there is a slight economic preference for Alternative A. If the differential escalation were expected to be somewhere in the 5-9% range, the manager would be more or less indifferent between Alternative A and B, and could proceed to judge them on other, qualitative merits.

Because several differential escalation rates have been included in the cost computations, there is nothing in the Example VII-8 analysis that could be construed as a specific forecast of price levels. Essentially, the onus of decision-making has been passed on to management. This is appropriate, since the prerogative of decision-making properly belongs to management, not the economic analyst. An economic analysis is simply a tool designed to aid the decision-maker by giving him more complete information.

Figure VII-5 amounts to a one variable breakeven uncertainty test, the test variable being the differential escalation rate. The reader might compare this example with Example VI-4. It is also possible to include escalation in two variable uncertainty tests such as Examples VI-6 through VI-8.

A sensitivity analysis approach may also be used to analyze inflationary impact in Type I economic analyses. By analogy to Figure VII-5, graphs may be drawn to portray the savings/investment ratio or payback period as a function of the differential escalation rate. Care is required, however, in the computation of escalated-discount payback periods. Specifically, Table C, Appendix E cannot be used to convert escalated SIR's to payback periods, because that table is based on standard 10% discount factors (Tables A and B, Appendix E).

The following examples develop two empirical methods for determining the payback period.

EXAMPLE VII-9: It is estimated that a $30,000 investment will save $6,000 in annually recurring costs (these are estimates in terms of base year prices). For an economic life of 15 years,

a. Compute the project SIR and payback period, assuming no extra escalation of annual costs (baseline comparison).

b. Recompute the SIR and payback period, assuming an extra 9%/year escalation in annual costs.

SOLUTION:

BASELINE COMPARISON:

$$\text{SIR} = \frac{\$6K(7.980)}{\$30K} = 1.6$$

Refer to the cash flow diagram of Figure VII-6, in which the upward arrows represent the stream of savings achieved as a result of the $30K investment. (There are actually two alternatives involved here, and cash flow diagrams could be drawn for each. The status quo diagram would show a 15 year stream of uniform annual costs. The investment alternative would have a similar stream of costs, but the annual amount would be $6K less than that for the status quo. Also, the diagram for the investment alternative would have the $30K investment cost incurred at Time Zero. Figure VII-6 amounts to a graphical shorthand in which the status quo cash flow diagram has been algebraically "subtracted" from the investment project's cash flow diagram. The single diagram conveys all the information necessary to assess the economic worth of the proposed project.)

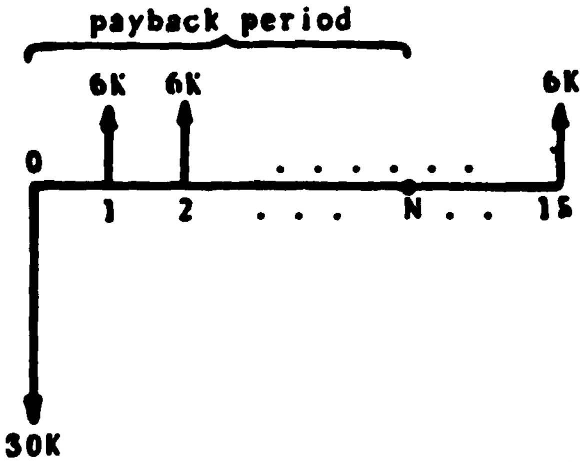


FIGURE VII-6

Let the unknown payback period be N years. A savings/investment ratio computed over this period will be precisely 1.0, since the payback period is by definition the time required to recover investment cost through accumulated present value savings. In symbols,

$$SIR_N = 1.0. \qquad \ldots (VII\text{-}2)$$

Writing the cumulative (Table B, Appendix E) N year discount factor as b_N, we have

$$\frac{\$6K \cdot b_N}{\$30K} = 1.0 \text{ yields } b_N = 5.$$

That is, the Table B factor corresponding to the payback period N is $b_N = 5$. Reference to Table B indicates that this result lies between the consecutive factors

$$b_6 = 4.570 \,, \quad b_7 = 5.108 \,.$$

Thus the payback period is somewhere between 6 and 7 years. Interpolating 5 between these two values yields the estimate

$$N = 6.8 \text{ years} \,.$$

REMARKS: In this case, the payback period could have been determined more easily by using Table C, Appendix E. (In the 15 year economic life column, the entry corresponding to a 1.6 SIR is 6.77 years.) Yet the method used above is very powerful; it does not require prior calculation of the life cycle SIR, and it can be employed even when Table C does not apply.

9% DIFFERENTIAL ESCALATION COMPARISON:

$$SIR = \frac{\$6K(14.018)}{\$30K} = 2.8$$

(14.018 is the 15 year cumulative factor from Appendix F, page F-7.)

Here Table C, Appendix E cannot be used to convert the 2.8 SIR into a payback period, because Table C is based on standard 10% discount factors, whereas this SIR has been computed with factors from page F-7. However, we can use the empirical method developed in the baseline comparison above:

Let N = Payback Period

Then $SIR_N = 1.0$

Yields $$\frac{\$6K \cdot B_N}{\$30K} = 1.0$$

(B_N = N year cumulative factor for 9% differential escalation)

$$B_N = 5$$

From page F-7,

$$B_5 = 4.887, \qquad B_6 = 5.839 .$$

Interpolation of $B_N = 5$ between these values yields:

$$N = 5.1 \text{ years}$$

The following example illustrates the effect of lead time on the discounted payback period.

EXAMPLE VII-10: Rework VII-9 with the assumption that a one year lead time intervenes between funding of the investment cost and commencement of the annual savings stream.

SOLUTION: The revised cash flow diagram is shown in Figure VII-7. Observe that the 15 year stream of savings has been deferred one year, so that the economic life now occupies Project Years 2-16 (instead of Years 1-15 as in Figure VII-6). It therefore becomes necessary to apply the difference between cumulative discount factors (specifically between 16 and 1 year factors) in the present value computations following. (See Rule 2, Subsection III-D.)

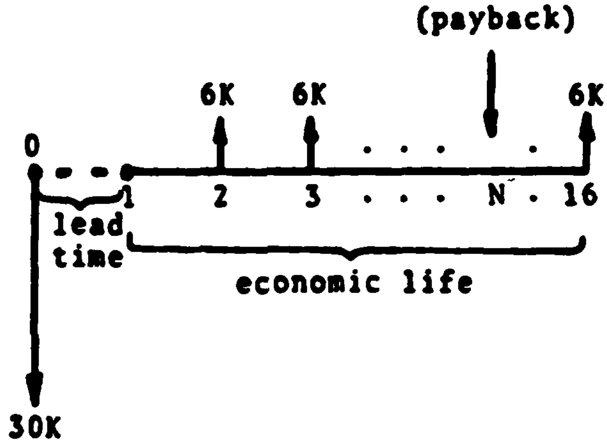


FIGURE VII-7

BASELINE COMPARISON:

$$SIR = \frac{\$6K(8.209 - 0.954)}{\$30K} = 1.45$$

$$N = \text{Payback Year}$$

$$SIR_N = 1.0 \text{ yields } \frac{\$6K(b_N - 0.954)}{\$30K} = 1.0$$

(b_N = N year cumulative factor from Table B, Appendix E)

$$b_N = 5 + 0.954 = 5.954$$

Interpolate between $b_8 = 5.597$ and $b_9 = 6.042$ to get

$$N = 8.8 \text{ years}$$

<u>9% DIFFERENTIAL ESCALATION COMPARISON:</u>

$$SIR_N = \frac{\$6K(14.886 - 0.995)}{\$30K} = 2.78$$

(14.886 and 0.995 are the 16 and 1 year cumulative factors, respectively, for 9% differential escalation from page F-7, Appendix F)

N = Payback Year

$$SIR_N = 1.0 \text{ yields } \frac{\$6K(B_N - 0.995)}{\$30K} = 1.0$$

(B_N and 0.995 are N and 1 year cumulative factors, respectively, from Appendix F, page F-7)

$$B_N = 5 + 0.995 = 5.995$$

Interpolate between $B_6 = 5.839$ and $B_7 = 6.781$ to get

$$N = 6.2 \text{ years}$$

The introduction of lead time requires a clarification in the definition of payback period. The periods N determined in the preceding examples above represent total elapsed time between initial funding and the point at which total investment has been amortized by cumulative discounted savings. The one year lead time is included in these periods, which might reasonably be called <u>total payback periods</u>. By contrast, the <u>operating payback period</u> measures only the actual period it takes savings to amortize investment exclusive of lead time. In the baseline and 9% differential escalation comparisons of Example VII-10, the operating payback periods are 7.8 and 5.2 years, respectively. For obvious reasons, it is the total payback period which is of concern in budgeting decisions. Accordingly, IT IS TOTAL PAYBACK PERIOD WHICH SHOULD BE COMPUTED AND SHOWN ON THE FORMAT A-1 (Appendix D) FOR TYPE I ECONOMIC ANALYSES.

Because Table C assumes no lead time between initial investment and the beginning of the savings stream, it cannot be used to estimate

the payback period directly (in the baseline comparison). The estimate derived from the table would be 7.82 years. (The SIR is 1.45, and 7.82 is halfway between 7.42 and 8.22, the payback periods for respective SIR's 1.5 and 1.4 in the 15 year life column.) However, adding the lead time to this figure gives 8.82 years, a very good approximation of the true payback period. In general, for non-escalated comparisons involving lead times, Table C may be used to estimate payback periods as follows: Calculate the (life cycle) SIR and read the corresponding entry from the appropriate economic life column; to this intermediate result, add the lead time to get the true payback period. (Alternately, use the formula provided in Appendix E.)

Comparison of the baseline SIR's and payback periods in Examples VII-9 and VII-10 shows that the presence of lead time makes a noticeable difference, all other things being the same. If a project is expected to require a lead time between the point of initial funding and the actual commencement of savings, the Type I economic analysis should be structured accordingly. Omission of the lead time will result in an overstatement of the proposed project's economic worth.

Example VII-11 illustrates a graphical method for determining the discounted payback period when several differential escalation rates are involved.

EXAMPLE VII-11: Suppose that the investment described in Examples VII-9 and VII-10 will provide an additional \$3K savings annually. However, while the original \$6K annual savings represented a reduction in costs expected to escalate at 9% above the general inflation rate, the additional \$3K annual savings is associated with costs which are expected to esclate at 7% above the general inflation rate. Calculate a revised SIR and payback period for the project. (As in Example VII-10, assume a one year lead time.)

SOLUTION: Details of the baseline analysis are not shown here; the procedure is the same as that of Example VII-10, except that the annual savings are \$9K (\$6K + \$3K) instead of \$6K. The reader may verify that the SIR is 2.18 and the (total) payback period is approximately 5.5 years. The escalated cost comparison follows:

$$\text{SIR} = \frac{\$6K(14.886 - 0.995) + \$3K(12.930 - 0.986)}{\$30K} = 3.97$$

(14.886 and 0.995 are the 16 and 1 year cumulative factors, respectively, for 9% differential escalation, Appendix F; 12.930 and 0.986 are the 16 and 1 year cumulative factors, respectively, for 7% differential escalation, Appendix F).

Determination of the payback period is complicated by the presence of more than one differential escalation rate. The empirical procedure used in Examples VII-9 and VII-10 cannot be applied here, because there is no single set of differential escalation factors to produce an interpolated estimate; rather, factors from two different columns (page F-7, Appendix F) are needed to calculate total present value savings over any time period. However, a graphical approach may be employed, based on the following computations:

3 year savings = \$6K(2.959 - 0.995) + \$3K(2.879 - 0.986) = \$17.5K
5 year savings = \$6K(4.887 - 0.995) + \$3K(4.670 - 0.986) = \$34.4K

Initial computation of the savings for 3 years and 5 years indicates that the discounted payback period lies somewhere between 3 and 5 years, so the 4 year savings is then calculated:

4 year savings = \$6K(3.928 - 0.995) + \$3K(3.787 - 0.986) = \$26.0K

The 4 year cumulative discounted savings is less than the investment; therefore the discounted payback period is between 4 and 5 years. In Figure VII-8 the vertical axis measures present value dollars and the horizontal axis measures time (project years). The investment cost, \$30K, is plotted as a dashed horizontal line, and a cumulative present value savings curve is plotted on the basis of the savings calculations above. The intersection of these two curves determines the payback period on the time axis. The result, indicated by the calculations as well as the figure, is just under 4.5 years.

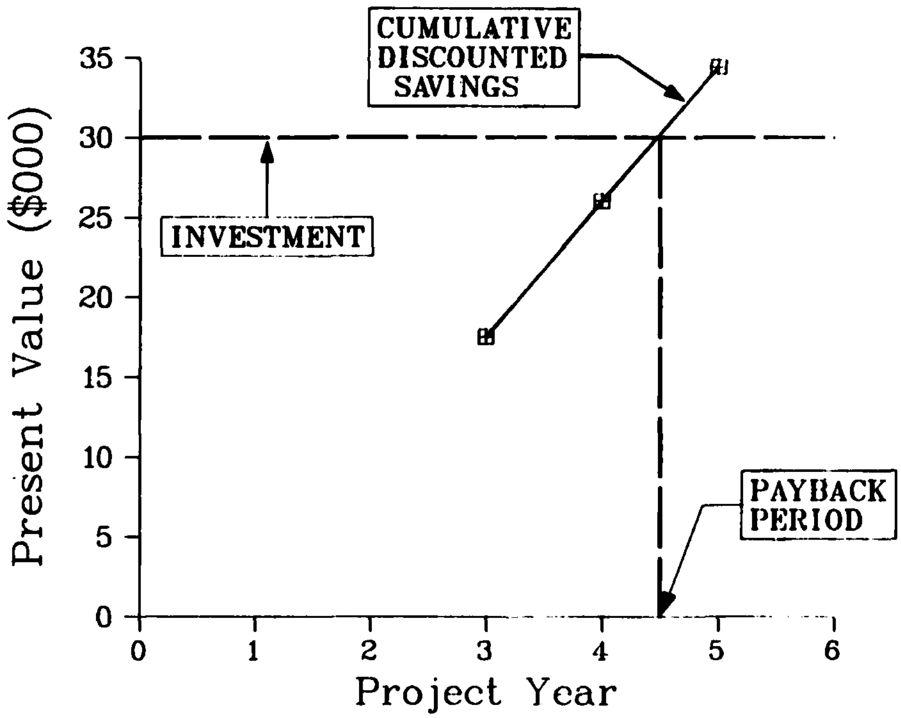


FIGURE VII-8

Note that in the SIR computation of Example VII-11, savings components which escalate at different rates must be treated separately, since they require escalated-discount factors from different (Appendix F) columns.

The periods for cumulative discounted savings calculations should be chosen so that one is shorter than the anticipated payback period and another is longer. (Observe that the 3 and 5 year periods chosen in Example VII-11 contain the actual payback period between them.) Then the payback period will be determined by a process of graphical interpolation rather than extrapolation when a curve is fitted to the savings points.

The graphical method of Example VII-11 can be generalized to treat any number of different savings component escalation rates.

E. SUMMARY AND COMMENTS

Use of the 10% real discount rate simplifies the treatment of inflation in an economic analysis because the 10% discount factors implicitly adjust for the general inflation rate -- whatever it may be. The key points for the analyst to keep in mind are:

1. The economic analysis should be performed in terms of constant dollars of the analysis base year.

2. When the base year is the same as the year of initial investment, current cost estimates must be escalated to the base year. This escalation includes both general inflation and real cost increases.

3. If it is expected that a particular annual cost element will have anomalous long term escalation behavior, an escalated dollar comparison may be performed. Only a differential escalation rate (the expected difference between the average long term general inflation rate and the long term escalation rate for the particular cost element) should be applied in the escalation of the base year annual cost element.

4. Differential escalation may be handled computationally by the use of differential escalation-discount factors which accomplish the operations of escalation and discounting simultaneously. It should be remembered that escalating and discounting of costs work at cross purposes. Costs are discounted because money commands a price for its use. Discount factors reduce future cash flows to present value equivalents in spite of inflation, not because of it. The higher the rate at which a cost is escalated, the more the impact of discounting is offset.

5. The pattern of annual costs can be non-uniform for reasons other than inflation; for example, maintenance costs may increase with the age of a physical asset or periodic maintenance costs may be incurred. These real cost variations should be reflected in the year by year cost estimates used in the analysis.

6. Because projections of future cost trends are very uncertain, the analyst should perform at least two comparisons: one without assumptions of differential escalation and another with assumptions of differential escalation. This is the minimum requirement for a check on the sensitivity of results to assumptions about cost trends.

7. When computing equivalent uniform annual cost for an alternative in which differential escalation is assumed for one or more cost elements, the NPV should be divided by the appropriate factor from Table B, Appendix E. Factors from Appendix F should be used only for computing the NPV to use in the numerator of the uniform annual cost equation (Equations III-8 and III-8a, Subsection III-F).

8. The fact that the effects of general inflation are incorporated in the 10% real discount rate simplifies the work of the analyst. It makes it unnecessary to project long term inflation rates as long as it can be assumed that all costs will escalate at about the general inflation rate. However, consider the case of an annual payment that is fixed in current dollars by a contract. In an inflationary period, an annual payment that is fixed in current dollars is a declining cost in terms of constant dollars (because the purchasing power, and hence value, of the current dollar is declining at the rate of inflation). Therefore, a negative differential escalation rate is applicable. To avoid projecting the general inflation rate, a sensitivity analysis approach should be employed in this type of case.

9. The use of differential escalation for energy costs is described in Appendix B.

VIII. DOCUMENTATION STANDARDS

A. INTRODUCTION

Throughout this handbook, the importance of adequate documentation has been stressed. Even the best analysis is of no use to the Navy if it is not properly communicated to the decision-maker. The decision-maker must have confidence that an analysis is complete and credible so that decisions can be based upon it. Furthermore, good economic analysis documentation can be invaluable for future program evaluation or for analysis of related problems.

B. ECONOMIC ANALYSIS SUBMISSION OUTLINE

While Formats A, A-1, and B, provided in Appendix D, are useful for economic analysis documentation, most economic analysis submissions will require more comprehensive documentation. The following outline is suggested as a guide for economic analysis submissions. The outline reflects the view that an economic analysis submission should be complete in itself -- the reader should not have to search other documents for information necessary for support and understanding of the analysis.

ECONOMIC ANALYSIS SUBMISSION OUTLINE

1. Summary

   This section should briefly summarize the entire analysis, with emphasis on the objective, alternatives, ranking of alternatives, conclusions, and recommendations.

2. Background/Objective/Requirements

   This section should include a succinct and unbiased objective statement as well as sufficient information to allow a reviewer, who may be unfamiliar with the situation, to understand the basis for the requirements.

3. Alternatives

   All alternatives investigated should be listed and defined.

4. Assumptions

   List and explain all assumptions used in the analysis.

5. Costs, Benefits, and Present Value Summaries

   This section should include the information presented on Formats A or A-1, and B (Appendix D of this handbook), with ranking of alternatives.

6. Sensitivity Analysis

Uncertainty and/or risk analyses performed on dominant cost elements, economic life, differential escalation rates, and other major assumptions.

7. Other Considerations

Any decision considerations which have not been treated in the preceding sections should be included here.

8. Conclusions/Recommendations

Ranking of alternatives with appropriate conclusions and recommendations based upon Sections 1-7.

9. Appendices

Detailed information supporting all cost and benefit estimates, including data sources, equations, projections, and calculations.

C. CHECKLIST FOR ANALYSTS AND REVIEWERS

The following checklist is provided as an aid for economic analysts and reviewers to help insure that economic analyses are correct, complete, and well-documented.

CHECKLIST

1. THE OBJECTIVE, ASSUMPTIONS AND ALTERNATIVES

   a. Is the problem stated the real problem?

   b. Is the objective, as stated, unbiased as to the means of meeting the objective?

   c. Are all reasonable assumptions identified and explained?

   d. Are assumptions too restrictive? Too broad?

   e. Are intuitive judgments identified as such? Are uncertainties treated as facts? Can the facts be verified?

   f. Are potential mission change constraints to the economic life of an alternative given due consideration? Has the impact of technological change been fully considered?

g. If a scenario has been used, is it realistic?

h. Are any feasible alternatives omitted?

i. Are the alternatives well defined and discrete? Do they overlap?

j. Have all provisions of economic analysis policy instructions listed in Appendix C been followed?

2. THE COST ESTIMATES

a. What cost estimating methods were used? Are they appropriate?

b. Are all relevant costs (including directly related support and training costs) included?

c. Are sunk costs properly excluded?

d. Are the sources of cost data indicated? Are these sources accurate and appropriate?

e. Have all cost estimates been made in base year constant dollars? What escalation projections were used?

f. If parametric cost estimating was used, are the Cost Estimating Relationships statistically valid? Are the estimates interpolated within the range of historical data or has extrapolation been used?

g. Was an average cost used where a marginal cost is appropriate?

h. Are cost factors current and supportable?

3. THE BENEFIT DETERMINATION

a. Does the analysis ignore some portion of total output?

b. Were the criteria used to measure benefit justified by the context of the study?

c. Was the benefit, in fact, unmeasurable? Has there been a rational assessment of nonquantifiable factors?

d. Was expert opinion used? Were these experts properly qualified?

e. If savings have been claimed, will a budget actually be reduced?

f. Have all advantages and disadvantages of the alternatives been identified? Are there any important externalities?

g. If an efficiency/productivity increase is projected, is there a documented need for greater output?

4. TIME DEPENDENT CONSIDERATIONS

a. Was lead time between the investment and the start of economic life accounted for?

b. Was present value analysis properly performed?

c. Are the economic lives used reasonable? Are they based upon guidelines?

d. Is terminal value important in this analysis?

e. If differential escalation has been assumed for a particular cost element, has the expectation that long term anomalous cost escalation will occur been adequately documented?

f. If lead time differs between alternatives, have the economic lives been aligned?

g. Have any relevant growth, "learning curve," and technological change predictions been incorporated in the analysis? Are they realistic?

5. THE SENSITIVITY ANALYSIS

a. If differential escalation was assumed, has a baseline analysis with no assumption of differential escalation been performed?

b. Has sensitivity analysis of the results to changes in dominant cost elements, economic life, etc., been performed? If not, why not?

c. Has breakeven analysis been performed?

d. Have all relevant "what if" questions been answered?

e. Have graphs been used to display sensitivity analysis information?

f. If a risk analysis has been performed, how were the probability estimates derived?

g. What do the sensitivity analysis results imply about the robustness of the ranking of alternatives?

6. SELECTING FROM ALTERNATIVES

a. Are the recommendations logically derived from the material?

b. Is interference from co-extensive or parallel operations ignored?

c. Are the recommendations feasible in the real world of political, cultural, or policy considerations?

d. Are the recommendations based upon significant differences between the alternatives?

APPENDIX A

ECONOMIC ANALYSES FOR SELF-AMORTIZING EXIGENT MINOR MILCON PROJECTS

INTRODUCTION

Exigent Minor MILCON (EMM) projects represent a special class of MILCON funded projects and are therefore accorded special treatment. As explained below, EMM projects may in some cases be justified on the basis of economics. Such projects must be supported by Type I economic analyses (see Subsection III-E). Because of the special nature of Exigent Minor MILCON projects, economic analyses supporting these projects are also somewhat specialized. It is for this reason that a discussion of EMM economic analyses has been reserved for this appendix.

EMM PROJECTS -- GENERAL BACKGROUND

Exigent Minor MILCON projects are accomplished by authority of 10 U.S.C. 2674. To qualify for EMM funding, a project must satisfy two criteria:

1A. It must be urgent in the sense that a) it relates to operations essential to the support of primary missions and tasks or to conditions hazardous to life and property; b) because of an existing or developing condition, the project cannot be deferred for inclusion in future military construction legislation, and there is no other alternative; and c) the project addresses a requirement which was not foreseeable.

OR

1B. The project must reduce current expenditures sufficiently to amortize the investment cost within a three year period.

2. The funded project cost must not exceed $500,000.

For additional details concerning statutory guidelines and limitations, funding authority, approval chains, and actual EMM project preparation and submission procedures, the reader is referred to OPNAVINST 11010.20 (current issue), "Facilities Projects Manual," Chapter 2. The remainder of this appendix will discuss the economic analyses associated with those construction projects costing between $100,000 and $500,000 which are to be justified under the EMM three year payback approval criteria.

ECONOMIC ANALYSES IN SUPPORT OF EMM PROJECTS

Formerly, funding of self-amortizing projects was specifically permitted by Public Law (PL) 91-145 amendment of 10 U.S.C. 2674. PL 95-82 of 1 August 1977 omitted the provision for three year payback projects; however, approval criteria for individual projects were not definitely set in law, thus allowing flexibility in criteria definition. The importance of self-amortizing projects is evident.

The significance of the three year payback criterion is tied to the normal MILCON cycle. For projects in the regular military construction program, an average of 36-42 months elapses between preparation of the DD Form 1391 and the date of contract award. By contrast, the approval process for EMM projects is expeditious, requiring at most only a few months. Thus, EMM projects with amortization periods of three years or less will essentially have "paid for themselves" during the time it would have taken merely to get them approved as part of a regular military construction program.

Economic analyses supporting self-amortizing projects are Type I in the sense discussed in Subsection III-E -- they must of necessity be comparing a status quo (existing situation) against a proposed alternative. Examples of self-amortizing EMM projects might include the following:

* Construction of a short section of pipeline, thereby eliminating trucking costs.

* Connection of two steam plants, permitting shutdown of one plant and enabling the other to carry the whole load.

* Extension of a primary station power distribution system to radar units, thereby eliminating the need for electrical generators at these locations.

Because of the special requirements for economic EMM projects, supporting economic analyses do not conform to normal guidelines as set forth in the main text of this handbook. Although EMM economic analyses are Type I analyses, no savings/investment ratio computation is necessary. Economic projects costing between $100,000 and $500,000 qualify for Exigent Minor funding if, and only if, the discounted savings in costs will amortize the investment cost within a three year period. Accordingly, the economic analysis need only establish a discounted payback period of three years or less.

Example A-1: Suppose Alternative A represents the status quo and Alternative B represents an alternate proposal (i.e., a proposed EMM project), with the following cost data:

ALTERNATIVE A:

Project Year	Recurring Cost
1	$245K
2	$245K
3	$245K

ALTERNATIVE B:

Project Year	Investment Cost	Recurring Cost
0	$230K	--
1	--	$160K
2	--	$145K
3	--	$145K

Then cumulative present value savings may be computed:

Project Year	Alt. A Cost	Alt. B Cost	Savings	Discount Factor	P.V. Savings	Cumulative P.V. Savings
1	$245K	$160K	$ 85K	.954	$81.1K	$ 81.1K
2	$245K	$145K	$100K	.867	$86.7K	$167.8K
3	$245K	$145K	$100K	.788	$78.8K	$246.6K

Note that the cumulative present value of savings for three years, $246.6K, is greater than the investment cost of $230K for Alternative B, so Alternative B meets the three year discounted payback criterion. Since the cumulative present value of savings after two years, $167.8K, is not sufficient to amortize the investment, the discounted payback period must be between two and three years. The discounted payback period may be estimated via linear interpolation as follows:

Let x = Discounted payback period (yrs.)

$$\frac{x - 2}{3 - 2} = \frac{\text{Investment Cost - 2nd Yr. Cum. P.V. Savings}}{\text{3rd Yr. Cum. P.V. Savings - 2nd Yr. Cum. P.V. Savings}}$$

$$\frac{x - 2}{3 - 2} = \frac{\$230K - \$167.8K}{\$246.6K - \$167.8K}$$

$$\frac{x - 2}{1} = 0.79$$

$$x = 0.79 + 2 = 2.79$$

The discounted payback period is estimated to be 2.79 years.

For a formatted example of an economic analysis supporting an Exigent Minor MILCON project, see Example A-2.

CAVEAT

The economic guidelines set down in the OPNAVINST 11010.20 series are explicit. To be acceptable for EMM funding, a "self-amortizing" project must cause an existing function to be more economically accomplished as a result of the capital investment. Justification must be based strictly on HARD DOLLAR SAVINGS. Vague savings attributed to depreciation, increased productivity, or cost avoidance do not qualify. The government must be actually paying the costs claimed in Alternative A.

Personnel savings are very difficult to successfully claim. Civilian labor savings can only be claimed if: (1) the civilian positions are totally eliminated by a reduction in force (RIF), or (2) the involved civilians fill other billets that are open and authorized to be filled at the activity. "Auditable" savings must actually accrue as a result of the proposed Exigent Minor MILCON project. If the personnel remain in the same billets, doing other work such as working at a backlog of maintenance, no reduction in the activity operating costs occurs as a result of the project. (This would be a productivity increase.) Even though the personnel are working to reduce the backlog of maintenance, their salaries and fringe benefits are still paid, resulting in no "auditable" savings. However, if these personnel fill other open billets on station that need to be filled and for which funding is already available, and their old billets are eliminated, this elimination is considered justifiable savings in three year payback submissions. It must also be pointed out that only appropriated funds can be claimed as savings. If personnel are paid out of nonappropriated dollars, no savings can be claimed. Military personnel savings can be claimed only if the activity involved reduces its military billets as a result of construction.

The emphasis on hard dollar accountability applies to investment costs as well as savings. Terminal or assets replaced values should not be netted against investment costs unless direct cash receipts will accrue to the Government from the sale of assets. This policy is more restrictive than that applying to Type I economic analyses supporting regular military construction projects, in which properly documented continuing use value or alternative use value is allowable (see Section IV.) All investment items connected with the project must be shown in the total cost to be amortized within the three years. Items to be included along with the construction project are associated repair, collateral equipment, transportation, equipment installation, demolition and civilian relocation costs. All such items must be considered when investigating the economy of the project.

Finally, it is to be stressed that the documentation of source/derivation of cost estimates and assumptions, if important to regular economic analyses, is crucial to those supporting self-amortizing EMM projects. Such projects are funded solely on an economic basis, and if documentation is insufficient to establish credibility of costs and savings, chances for approval are extremely remote.

Example A-2: Following is an example adapted from an actual EMM analysis submission. It is intended to serve as a model for general format. The reader will note that a separate Format A is used to document costs for each alternative. This practice has become standard at NAVFAC Headquarters, despite the general use of Format A-1 for Type I economic analyses. The Format A is here considered more appropriate because, as discussed above, the general imputations allowed on the Format A-1 do not apply to EMM analyses unless a literal cash flow is involved. (For a complete display of formats, see Appendix D.)

COST ANALYSIS FOR
EXIGENT MINOR MILCON PROJECT P-999
DIVER TRAINING FACILITIES
NAVAL TRAINING CENTER, SAN FLORA, ECOTOPIA

I. Background, Objective, and Alternatives

This analysis investigates the economy of replacing an existing barge and three small buildings at the Naval Station, San Flora, used for conducting underwater diver training, with new and existing facilities at the nearby Naval Amphibious Base, San Flora. Present facilities are in need of extensive repair and are within the waterfront operations area of the Naval Station. Existing facilities are also located within an Explosives Safety Quantity-Distance (ESQD) arc.

The objective is to continue the Second Class Diver Training mission in the most economical manner. The alternatives are:

Alternative A - Continue at Naval Station ("Status Quo")

The Second Class Diving School is currently housed in three small buildings, which are in need of extensive repairs, and one barge. The barge is overdue for a complete overhaul which has been scheduled for FY 19x0 and budgeted at $750,000. The barge is a 25 year old vessel used for instructions in diving. The barge contains classrooms and is used tied up to a pier; it is not towed to deep water.

Alternative B - Relocate to Naval Amphibious Base (NAB)

It is proposed to build (through Project P-999) a 6,375 square foot addition to Building 107 at NAB which will contain classrooms, offices, storage and shop areas and to construct a new diving float adjacent to Pier 5 to house various diving apparatus. The estimated construction cost is $480,000; collateral equipment required is estimated at $53,200. The barge will be retired to salvage.

II. Discounted Payback Summary

The costs for Alternatives A and B are discussed in Attachments "A" and "B", respectively. The following is a summary of Present Value (PV) costs for three years:

	Alternative A	Alternative B
Investment	0	$533,200
PV 3 year O&M	$769,704	48,090

Cumulative Present Value Savings are:

Project Year	Alt. A Cost	Alt. B Cost	Savings	Discount Factor	PV Savings	Cumulative PV Savings
1	$786,000	$40,000	$746,000	.954	$711,684	$711,684
2	12,000	6,000	6,000	.867	5,202	716,886
3	12,000	6,000	6,000	.788	4,728	721,614

Payback occurs within the first year. The discounted payback period is estimated, using linear interpolation, as:

x = Discounted Payback Period in years

$$\frac{x - 0}{1 - 0} = \frac{\$533,200 - 0}{\$711,684 - 0} = 0.75$$

The discounted payback period is 0.75 year, well within the three year payback criterion.

III. Assumptions

1. Utilities consumption will be approximately equal for both alternatives and is not included in the cost summaries of this analysis. Electrically operated equipment will be the same. Total area of new facilities will be approximately the same as the area of existing facilities.

2. Personnel needed for training operations and nonfacility costs directly related to the training function will be the same for either alternative.

3. The Naval Station will have to repair Buildings 191, 425, and 470, either for continuation of the Diver Training School or for any new occupant. Although a new occupant of the repaired buildings would perform a function different than diver training, the budgetary impact is the same. Therefore, repair costs for these buildings are included for both alternatives.

IV. Cost and Present Value Summaries

Costs for Alternatives A and B are summarized on the attached Format A's; cost estimates and sources are detailed in Attachments "A" and "B".

V. Other Considerations

An Environmental Impact Assessment has been made and it has been determined that the proposed project will not have a significant impact on the environment and is not highly controversial. If the project is not implemented, the School will continue to operate within the waterfront operations area of the Naval Station encumbered by an ESQD arc. If Alternative B is implemented, training can continue uninterrupted during project accomplishment; however, if Alternative A is chosen training will be interrupted by the barge overhaul and building repairs.

VI. Conclusion and Recommendation

Implementation of Alternative B will provide a rapid payback primarily through saving FY 19x0 funds from the small craft overhaul budget. This conclusion is not sensitive to the assumptions and estimates made in this analysis. Therefore, it is recommended that Project P-999, Diver Training Facilities, be funded through the Exigent Minor MILCON program.

ECONOMIC ANALYSIS - DEPARTMENT OF THE NAVY INVESTMENTS
SUMMARY OF PROJECT COSTS

FORMAT A

1. Submitting DOD Component: Department of the Navy

2. Date of Submission: 1 Jan 19x0

3. Project Title: Diver Training Facilities P-999

4. Description of Project Objective: Continue Second Class Diver Training mission

5. Alternative: A - Continue at NS 6. Economic Life: Three Year Payback Criterion

8. Project Costs						
7. Project Year(s)	a. Nonrecurring		b. Recurring Operations	c. Annual Cost	d. Discount Factor	e. Discounted Cost
	R&D	Investment				
1	0	0	$786,000	$786,000	.954	$749,844
2	0	0	12,000	12,000	.867	10,404
3	0	0	12,000	12,000	.788	9,456
9. TOTALS			$810,000	$810,000		$769,704

10a. Total Project Cost (discounted) $769,704

10b. Uniform Annual Cost (without terminal value) ______

11. Less Terminal Value (discounted) ______

12a. Net Total Project Cost (discounted) $769,704

12b. Uniform Annual Cost (with terminal value) ______

ECONOMIC ANALYSIS - DEPARTMENT OF THE NAVY INVESTMENTS
SUMMARY OF PROJECT COSTS
FORMAT A

13. Source/Derivation of Cost Estimates:

All Cost estimates are in FY 19x0 constant dollars.

SEE ATTACHMENT "A"

a. Nonrecurring Costs:

(1) Research & Development

(2) Investment

b. Recurring Costs:

c. Net Terminal Value:

d. Other Considerations:

See Section V of this analysis.

14. Name & Title of Principle Action Officer	DATE
CDR N. G. Near, PWO San Flora	1/1/x0

ATTACHMENT "A" FOR ALTERNATIVE A

Present operations are conducted on a barge and in three small buildings. Extensive repairs are needed on all facilities, must be accomplished in the first year, and have already been budgeted to be performed in the first year.

Operation and Maintenance Costs

A. First Year

1. Overhaul and Repairs

a. Barge - This cost estimate is based upon the Small Craft and Boats Accounting Report (SABAR). The YFNX-24 barge is a 25 year old vessel used for instruction in diving and has deteriorated considerably along with original equipment including the basic electrical system. The last drydocking and overhaul was 10 years ago. (The normal cycle is three years.)

Because of the condition of the barge and in accordance with CNO direction, repairs and maintenance as described in the following estimate plus other maintenance or repair items that may become apparent while the barge is in drydock will be funded if P-999 is not approved. The FY 19x0 overhaul budget includes $750,000 earmarked for this purpose.

The single most important feature is the overhaul and repair of the hyperbaric chambers. (This is also the most costly feature.) The chambers (decompression) do not meet current criteria for certification. They continue to be used, however, based on older less restrictive certification criteria. NAVSEA rules require that the chambers be updated to meet new criteria during the next normal maintenance cycle. The hyperbaric chambers will be discarded if P-999 is approved, as existing chambers at the new site are available for this training.

Estimated overhaul costs for YFNX-24:

(1)	Sewage disposal system	$ 37,400
(2)	Repairs to classrooms and head	30,000
(3)	Repair and overhaul hyperbaric chambers	285,000
(4)	Docking/undocking, berthing and services	31,000
(5)	Craft preservation (hull, housing structure)	99,400
(6)	Fendering replacement	47,500
(7)	Electrical system repair	123,200
(8)	Steam and water system repairs (galvanic protection	73,500
(9)	Void preservation	23,000
		$750,000

(Although not included in the three year period addressed by this payback analysis, the barge would also require later expenditures of approximately $115,000 every three years on the normal cycle for routine overhaul which includes craft preservation and void preservation.)

b. Bldgs. 191, 425 and 470

Repairs are needed on these buildings. Work consists of reroofing, repair/replacement of flooring, electrical rewiring, and replacement of light fixtures and painting. Assumed cost is based on Public Works Department estimates.

Estimated Cost = $ 36,000

2. Maintenance - no significant maintenance costs are expected for the first year.

Total First Year Cost = $786,000

B. Annual Cost for the Remaining Two Years

1. Repairs - no further repairs required

2. Maintenance

a. Barge - Work consists of painting the inside of the barge on an annual basis and painting the outside twice a year. Estimated cost for painting is $9,000. A nominal sum of $1,000 is assumed for preventative maintenance and minor repairs. Thus,

$$\$9,000 + \$1,000 = \$10,000$$

b. Bldgs. 191, 425 and 470

Annual maintenance for these three buildings is estimated at $2,000, based upon Public Works Dept. records.

$\underline{\$\ 2,000}$

Total Annual Cost = $12,000

ECONOMIC ANALYSIS - DEPARTMENT OF THE NAVY INVESTMENTS
SUMMARY OF PROJECT COSTS

FORMAT A

1. Submitting DOD Components: Department of the Navy

2. Date of Submission: 1 Jan 19x0

3. Project Title: Diver Training Facilities

4. Description of Project Objective: Continue Second Class Diver Training mission

5. Alternative: B - Relocate to NAB

6. Economic Life: Three Year Payback Criterion

8. Project Costs						
7. Project Year(s)	a. Nonrecurring R&D	a. Nonrecurring Investment	b. Recurring Operations	c. Annual Cost	d. Discount Factor	e. Discounted Cost
0	0	$533,200	0	$533,200	1.000	$533,200
1	0	0	40,000	40,000	.954	38,160
2	0	0	6,000	6,000	.867	5,202
3	0	0	6,000	6,000	.788	4,728
9. TOTALS		$533,200	$52,000	$585,200		$581,290

10a. Total Project Cost (discounted) $581,290

10b. Uniform Annual Cost (without terminal value) ______

11. Less Terminal Value (discounted) ______

12a. Net total Project Cost (discounted) $581,290

12b. Uniform Annual Cost (with terminal value) ______

ECONOMIC ANALYSIS - DEPARTMENT OF THE NAVY INVESTMENTS
SUMMARY OF PROJECT COSTS
FORMAT A

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13. Source/Derivation of Cost Estimates:

All cost estimates are in FY 19x0 constant dollars.

SEE ATTACHMENT "B"

a. Nonrecurring Costs:

(1) Research & Development

(2) Investment:

b. Recurring Costs:

c. Net Terminal Value:

d. Other Considerations:

See Section V of this analysis.

14. Name & Title of Principal Action Officer CDR N. G. Near, PWO San Flora	DATE 1/1/x0

ATTACHMENT "B" FOR ALTERNATIVE B

Proposed project will relocate the Divers' School from the Naval Station to the Naval Amphibious Base (NAB). The barge will be retired to salvage.

Investment Costs:

Construction: Estimate prepared by A/E firm using industrial engineering method of cost estimating based upon take-off from designs for building extension and float. SIOH included.

$480,000

Collateral Equipment: Based on list of furniture, lockers, equipment, etc., at delivered prices (supplied through GSA).

$ 53,000

Total Investment Cost = $533,000

Operation Costs:

A. First Year

1. Repairs

a. Bldgs. 191, 425, and 470 - The Naval Station will have to repair these buildings for any new occupant. Work will be the same as Alternative A.

Estimated Cost = $36,000

(See Attachment "A")

2. Maintenance

a. NAB Bldg 107, float $ 4,000

Total First Year Cost = $40,000

B. Annual Cost for the Remaining Two Years

1. Maintenance

a. Bldgs. 191, 425, 470 - Continued annual maintenance for these three buildings.

Estimated Cost = $2,000

b. NAB Bldg 107, float $4,000

APPENDIX B

GUIDELINES FOR

ENERGY RELATED ANALYSES

INTRODUCTION

Generally, all facilities must be designed for minimal energy consumption. This policy is further discussed in NAVFACINST 11010.14M, "Project Engineering Documentation (PED) for Proposed Military Construction Projects" of 14 Dec 1978. Executive Order 12003 of 20 July 1977, specifies certain energy goals for all Federal buildings. For new buildings the goal is a 45% reduction in the average annual energy required by 1985, when compared to the average annual energy requirement of a building in 1975. For existing buildings Executive Order 12003 specifies a goal of 20% reduction in the average annual energy used on the same basis. Accordingly, when analyzing energy conserving measures economic analysis methods employing life cycle cost techniques shall be used. Additionally, for fuel consuming projects NAVFACINST 11010.14M describes national policy on utility systems and industrial-size plants. In the development of plant projects, an economic analysis is also required to determine the optimum design for power plants and supporting facilities.

The general guidance for energy related projects is that economics guides the decision among alternatives. Exceptions for solar or other renewable energy investments have been made as a result of the "energy crisis." Special cases for solar related systems should be examined where they appear to have potential economic feasibility. Recent MILCON authorization acts have given solar installations economic preference to stimulate the industry. The FY-80 act requires that all Military Construction projects, including family housing, shall include solar energy systems to the extent that analysis demonstrates it to be cost effective. Solar systems are legislatively defined to be cost effective if the original investment cost differential can be recovered over the expected life of the facility. In conducting the life cycle cost analysis, the solar system O&M cost differential will be considered to be zero and all calculations will be based on undiscounted, escalated dollars. This legislative guidance changes periodically and care should be taken to assure that the latest guidance is being followed.

ECIP AND ETAP

The conservation of energy is an important national goal. Every year, the Navy allocates significant resources to reduce energy comsumption at Naval shore activities by retrofitting existing facilities. These energy conservation retrofit projects usually show high energy and cost savings. The submission of energy projects and supporting economic analysis documentation are required in accordance with the guidance of two programs:

1. Energy Conservation Investment Program (ECIP).

2. Energy Technology Application Program (ETAP).

ECIP provides for accomplishment of MILCON projects of more than $100,000 investment cost which retrofit existing facilities. ECIP projects are funded under a dedicated program within the regular MILCON program. Submissions of ECIP projects are in accordance with the guidance of NAVFACINST 11010.44 series and must meet the criteria and formats of CNO letter 44/720848 of 27 July 1978. Similar guidance for family housing projects is contained in NAVFAC letter 08/MCM of 31 May 1978, "Energy Conservation Investment Program (ECIP), Guidance for Family Housing." ECIP projects must be cost effective based on a savings/investment ratio greater than one, as shown by a life cycle cost analysis. ECIP projects may combine similar work in various buildings in order to reduce contract costs. When preparing ECIP life cycle cost analyses, prescribed long term differential escalation rates are to be used for computing discounted savings.

ETAP provides for accomplishment of smaller energy conservation retrofit projects which cannot be funded under the ECIP program. ETAP is a NAVFAC centrally managed and O&MN funded program for rapid payback facility retrofit projects. Submission of ETAP projects must be in accordance with NAVFACNOTE 4101 of 20 July 1978 and NAVFAC letter 1130/WEE of 21 September 1978. The procedures for ETAP projects are almost identical to ECIP procedures. The ETAP projects must be cost effective, may include multiple category codes, and may group separate small tasks to meet the funding minimums. However, ETAP projects are limited to the correction of deficiencies requiring investment of between $5,000 and $100,000.

DEPARTMENT OF ENERGY LIFE CYCLE COSTING RULES

Executive Order 12003 directed Federal agencies to consider in their building plans only energy conservation improvements which are life cycle cost effective and to give the highest priority to the most cost effective projects. The Executive Order also required the Department of Energy (DOE) to provide procedures to Federal agencies for estimation of life cycle costs and savings of proposed energy conservation, and for comparison of cost effectiveness in a consistent manner throughout the Federal Government.

The National Energy Conservation Policy Act of 1978 also contained provisions for the establishment of life cycle costing procedures by the Department of Energy in consultation with the National Bureau of Standards (NBS) and the General Services Administration (GSA). The basic set of life cycle costing rules included in the Federal Energy Management Program (FEMP) Rules, as established by Part 436, Subpart A, in Title 10 of the U.S. Code of Federal Regulations, was published in the Federal Register, Vol. 45, No. 16, of 23 January 1980. Explanations and procedures for application of these rules are described in the Life-Cycle Costing Manual for the Federal Energy Management Program, which was prepared by NBS for DOE.

The DOE rules apply to consideration of both the cost effects of replacing building systems with energy-saving alternatives in existing Federal buildings, and of selecting among alternative building designs containing different energy-using building systems for new Federal buildings. At the time of publication of this handbook, the Department of Defense had not yet issued implementing instructions for the DOE rules. Nevertheless, the analyst should be familiar with these procedures so that, <u>when directed</u>, they can be incorporated in energy related analyses.

The reader who has studied the information in Sections II, III, IV, V and VII of this handbook is well prepared for conducting an analysis as described in the NBS Manual. Key features of the DOE rules and differences from the previously discussed procedures are:

1. The DOE rules employ end of year discount factors rather than the continuous compounding factors of DODINST 7041.3. (Refer to Subsection III-D. The DOE and DOD factors both incorporate a 10% effective annual discount rate. The DOD factors compound a lower nominal rate continuously to achieve a 10% effective annual rate--this is consistent with the assumption that cash flow is continuous throughout the year. The DOE factors reflect the simplifying assumption that cash flows occur at the ends of years. Since compounding is annual, the nominal annual discount rate and the effective annual discount rate are both 10%.) A set of end of year discount factors is displayed in Table B-1. Single Present Worth (SPW) factors are analogous to the single amount factors of Table A, Appendix E, and are to be used for nonfuel, nonrecurring costs. Uniform Present Worth (UPW) factors are analogous to the cumulative uniform series factors of Table B, Appendix E, and are to be used for nonfuel, annually recurring costs.

2. DOE establishes energy prices and differential escalation rates to be used in the analysis. Actual prices paid may be used in analyses if they are higher than the DOE energy prices.

It has been argued that changes in Federal energy use have an impact at the margin and the prices should therefore be based on marginal prices rather than average prices. DOE is considering using marginal prices and is also considering adjusting prices to reflect externalities. (Refer to Subsection V-H for a definition of externalities.)

Future energy prices and differential escalation rates are forecasted by DOE's Energy Information Administration (EIA). Energy price differential escalation rates are projected for 10 geographic regions for electricity, natural gas, liquid gas, distillate, residual, and coal. Separate projections are made for the residential, commercial, and industrial sectors. Three differential escalation rates are projected for each combination of region, sector, and fuel

type--one for the first 5 years of the study period, one for the next 5 years, and one for the remainder of the study period. Since these projections are periodically updated, the analyst should ensure that the most recent projection is used in the analysis.

The EIA energy price differential escalation rate projections have been incorporated in tables of "UPW Discount Factors Adjusted for Energy Price Escalation." These factors are analogous to the cumulative uniform series differential escalation-discount factors of Appendix F and are used in a similar manner. The analyst may use these tables or compute factors using the formula provided in the Federal Register and in the NBS Manual.

3. The DOE rules specify that no differential escalation is to be applied to nonfuel costs.

4. The base year (zero point) is the year in which the analysis is performed. Therefore all costs and benefits are estimated in terms of analysis year constant dollars and are discounted to the analysis year "present" in the present value calculations. Usually the initial investment will occur at some point other than the base year and the analysis year constant dollar investment cost will differ from the budget year current dollar investment cost. (Refer to Subsection IV-G for a discussion of constant and current dollars.) Because the differential escalation projections mentioned in (2) above apply to specific years, care should be taken to ensure that differential escalation factors are applied properly in relation to the base year.

5. The maximum building life to be used is set at 30 years. The rules state that the useful life of any major building renewal or overhaul may be estimated by the manufacturer, engineer or architect, or other reliable source.

6. Until a more adequate method of accounting for external benefits is developed, DOE requires Federal agencies to assume an investment credit of 10 percent of the initial investment cost of both conservation and renewable energy investments as a proxy for externality adjustments. In other words, each analysis will assume that the initial cost is 90 percent of the actual investment cost. The 10 percent figure is based upon Federal and state tax credits which represent legislative valuations of the external benefits of fossil fuel conserving investments.

7. Ranking measures used in the DOE rules are referred to as "modes of analysis." Replacement of a building system with an alternative building system is considered cost effective if:

a. Total Life Cycle Costs (TLCC) are estimated to be lower (TLCC is equivalent to net present value (NPV) of life cycle costs as discussed in Section III),

b. Net Savings are estimated to be positive (Net Savings is the difference in TLCC's for the existing and proposed alternatives), or

c. The Savings-to-Investment Ratio (SIR) is estimated to be greater than one.

d. As a rough measure, Federal agencies may estimate simple payback time. The estimated simple payback time is the number of years required for the cumulative value of energy cost savings less future nonfuel costs to equal the investment cost required, without consideration of future fuel price increases or discount rates.

Alternative building designs for new Federal buildings are to be evaluated on the basis of TLCC. The alternative design which results in the lowest TLCC is deemed the most cost effective.

8. Federal agencies are encouraged to use formats similar to those in the NBS Manual.

9. The DOE rules specify the use of the 10% discount rate; however, this is under review by the Office of Management and Budget (OMB).

TABLE B-1

END OF YEAR DISCOUNT FACTORS

Study Period Year	SPW Factor	UPW Factor
1	0.909	0.909
2	0.826	1.736
3	0.751	2.487
4	0.683	3.170
5	0.621	3.791
6	0.564	4.355
7	0.513	4.868
8	0.467	5.335
9	0.424	5.759
10	0.386	6.145
11	0.350	6.495
12	0.319	6.814
13	0.290	7.103
14	0.263	7.367
15	0.239	7.606
16	0.218	7.824
17	0.198	8.022
18	0.180	8.201
19	0.164	8.365
20	0.149	8.514
21	0.135	8.649
22	0.123	8.772
23	0.112	8.883
24	0.102	8.985
25	0.092	9.077
26	0.084	9.161
27	0.076	9.237
28	0.069	9.307
29	0.063	9.370
30	0.057	9.427

APPENDIX C

ECONOMIC ANALYSIS POLICY INSTRUCTIONS

This appendix lists relevant economic analysis instructions in effect as of the date of publication of this handbook. It is the responsibility of the analyst to ensure that current guidance is followed in the preparation of economic analyses.

A. BASIC ECONOMIC ANALYSIS INSTRUCTIONS

1. OMB Circular No. A-94 (Revised) (27 March 1972). Subj: "Discount Rates to be Used in Evaluating Time-distributed Costs and Benefits" -- prescribes the 10% discount rate for general use in the economic evaluation of U. S. Government programs and projects; cites general policy for the treatment of inflation in such economic evaluations; does not apply to the evaluation of decisions regarding acquisition of commercial-type services by Government or contractor operation (guidance for which is OMB Circular No. A-76 (Revised)).

2. DODINST 7041.3 (18 October 1972). Subj: "Economic Analysis and Program Evaluation for Resource Management" -- establishes policy and procedural guidance for a) economic analysis of proposed DOD programs, projects, and activities, and b) program evaluation of ongoing DOD activities; presents suggested formats, definitions of terms, and tables of 10% discount factors for use in economic analyses and program evaluations.

3. DOD 4270.1-M (Advance Edition) (1 June 1978). Subj: "DOD Construction Criteria Manual" -- requires that life cycle costs be considered in engineering economic studies which are requisite to the design of military facilities.

4. SECNAVINST 7000.14B (18 June 1975). Subj: "Economic Analysis and Program Evaluation for Navy Resource Management" -- implements the DODINST 7041.3 within the Department of the Navy; outlines specific area of action responsibility for the Secretary of the Navy (Financial Management), the Comptroller of the Navy (NAVCOMPT), the Chief of Naval Operations (CNO), and the Commandant of the Marine Corps (CMC).

5. OPNAVINST 7000.18 (27 July 1973). Subj: "Economic Analysis and Program Evaluation for Navy Resource Management" -- implements the SECNAVINST 7000.14 series within all activities under the command of the Chief of Naval Operations; outlines specific areas of action responsibility within the Office of the Chief of Naval Operations; tasks the Chief of Naval Material to a) support OPNAV with on-request economic analyses for programs under NAVMAT cognizance, and b) assist OPNAV with supporting data when OPNAV has the action on an economic analysis.

B. RELEVANT NAVFAC DIRECTIVES

1. NAVFACINST 11010.14M (14 December 1978). Subj: "Project Engineering Documentation (PED) for Proposed Military Construction (MILCON) Projects" -- provides procedures for submission of engineering data and documents to support Military Construction Projects.

2. <u>NAVFACINST 11010.32E (7 December 1977)</u>. Subj: Military Construction Program Projects; preparation of supporting documents for" -- provides specific guidance for the preparation of documentation for projects proposed for inclusion in the Military Construction (MILCON) Program. (NOTE: A revised instruction is expected to be issued during 1980.)

3. <u>NAVFACINST 11010.44D (19 November 1979)</u>. Subj: "Shore Facilities Planning Manual" -- provides procedures and guidance for the Shore Facilities Planning System.

C. ENERGY POLICY DIRECTIVES

The following directives and instructions establish policy for energy related economic analysis. Submittals of MILCON energy projects must also meet the requirements for MILCON projects discussed in Subsection A of this appendix.

1. <u>Executive Order 12003 (20 July 1977)</u>. Establishes energy conservation goals and requires an economic analysis based on present worth techniques.

2. <u>Federal Register, Vol. 45, No. 16 (23 January 1980)</u>. Subj: "Federal Energy Management and Planning Programs; Methodology and Procedures for Life Cycle Cost Analysis" -- provides Department of Energy rules and regulations for conservation and solar energy life cycle cost analysis.

3. <u>NAVFACNOTE 4101 (20 July 1978)</u>. Subj: "Navy Shore Facilities Energy Engineering Program" -- this defines the NAVFAC Energy Engineering Program (EEP).

4. <u>CNO ltr ser 44/720848 (27 July 1978)</u>. Subj: "Energy Conservation Investment Program (ECIP) Guidance" -- provides criteria and guidance for candidate ECIP MILCON projects.

5. <u>NAVFAC ltr 08/MCM (31 May 1978)</u>. Subj: "Energy Conservation Investment Program (ECIP), Guidance for Family Housing" -- provides economic analysis format and content guidance for family housing ECIP projects. NOTE: It is anticipated that this guidance will be superseded by the publication of NAVFAC P-930, <u>Navy Family Housing Manual</u>, Chapter 20, in 1980.

D. COMMERCIAL/INDUSTRIAL POLICY DIRECTIVES

The following chain of instructions establishes policy regarding the acquisition of commercial or industrial products for Government/DOD/Navy use. Where applicable, economic evaluation procedures are prescribed. These procedures are self-contained; they do <u>not</u> conform to the economic analysis guidance of this handbook (i.e., the guidance prescribed by the OMB Circular No. A-94/DODINST 7041.3 chain cited in Part A), but are under the OMB Circular No. A-76 policy.

1. OMB Circular No. A-76 (Revised) (29 March 1979). Subj: "Policies for Acquiring Commercial or Industrial Products and Services Needed by the Government" -- this reaffirms the Government's general policy of reliance on the private sector for goods and services.

2. Cost Comparison Handbook: Supplement No. 1 to OMB Circular A-76 No. (March 1979) -- provides detailed instruction for developing comprehensive cost comparisons for acquiring a product or service by contract vs. providing it with in-house Government resources.

3. DOD Directive 4100.15 (22 February 1980). Subj: "Commercial or Industrial Activities" -- prescribes Department of Defense policy governing the establishment and operation of DOD commercial or industrial activities by DOD components.

4. DODINST 4100.33 (22 February 1980). Subj: "Commercial or Industrial Activities - Operation of" -- implements criteria for use by the Military Departments and Defense Agencies in regard to the commercial or industrial activities which they operate and manage.

*5. SECNAVINST 4860.44B (4 April 1975). Subj: "Commercial or Industrial Activities Program" -- assigns responsibility for implementing the Commercial or Industrial Activities Program within the Department of the Navy.

*6. OPNAVINST 4860.6B (28 November 1975). Subj: "Commercial or Industrial (C/I) Activities Program" -- emphasizes the requirements of the Commercial or Industrial Activities Program throughout the Navy.

*7. NAVMATINST 4860.12A (25 January 1972). Subj: "Commercial or Industrial (C/I) Activities Program" -- promulgates Department of the Navy policy and procedures which apply to commercial or industrial activities or contract support services.

*NOTE: NEW INSTRUCTION MAY BE ISSUED DURING 1980.

E. AUTOMATIC DATA PROCESSING (ADP) POLICY

The following chain of instructions establishes policy and guidance for the acquisition of ADP equipment and services:

1. FPR Part 1-4.11 (October 1976), "Procurement and Contracting for Government-Wide ADPE, Software, etc."

2. FPMR 10-35.2 (July 1974), "Management, Acquisition and Utilization of Automatic Data Processing."

3. OMB Circular No. A-109 (April 1976). Subj: "Major System Acquisition."

4. DOD Directive 7920.1 (October 1978). Subj: "Life Cycle Management of Automated Information Systems (AIS)."

5. DODINST 7920.2 (October 1978). Subj: "Major Automated Information Systems Approval Process."

6. SECNAVINST 5231.1A (November 1979). Subj: "Management of Life Cycle Automated Information Systems within the Department of the Navy."

7. SECNAVINST 5230.6 (November 1979). Subj: "ADP Approval Authority and Acquisition/Development Thresholds; delegation of."

8. SECNAVINST 5236.1A (April 1974). Subj: "Specification, Selection and Acquisition of Automatic Data Processing Equipment (ADPE)."

F. LEASE VS. PURCHASE OF REAL PROPERTY

1. OMB Circular No. A-104 (14 June 1972). Subj: "Comparative Cost Analysis for Decisions to Lease or Purchase General Purpose Real Property" -- establishes specialized procedures for the economic analysis of general purpose real property buy vs. lease options. These procedures diverge from the guidance prescribed in the OMB Circular No. A-94/DODINST 7041.3 chain (Subsection A, page C-2). A 7% discount rate is specified to take account of the special tax treatment of real property in the U.S. (See, however, DODINST 7041.3, 18 October 1972, Encl. 2, page 9, paragraph (b).) Inclusion of imputed taxes and insurance premiums and calculation of residual value using obsolescence and decay factors are prescribed.

2. DODINST 4165.12 (23 July 1973). (With Change 1 of 28 December 1976) Subj: "Prior Approval of Real Property Actions" -- requires an economic analysis in accordance with DODINST 7041.3 when a proposed leasehold is in lieu of new construction.

3. DASD (I & H) Memo (9 January 1980). Subj: "Economic Analysis concerning Leasing of Real Property; information on " -- reiterates requirement for economic analysis for all proposals to acquire space or family housing in the U.S., its territories and possessions, and overseas, to determine if leasing or construction is in the best interests of the government; notes that OMB has determined that the appropriate discount rate for overseas real property is 10%; prescribes an economic life of 25 years for properties which are intended to be occupied indefinitely.

APPENDIX D

FORMATS FOR ECONOMIC ANALYSIS SUBMISSIONS

NOTE: The above formats have been adapted from those appearing in DODINST 7041.3.

TYPE II ECONOMIC ANALYSIS
SUMMARY OF COSTS
FORMAT A

1. Submitting Department of the Navy Component: ______________________

2. Date of Submission: ______________________

3. Project Title: ______________________

4. Description of Project Objective: ______________________

____

5. Alternative: ______________________

6. Economic Life: ______________________

8. Program/Project Costs						
7. Project Year(s)	a. Nonrecurring		b. Recurring Operations	c. Annual Cost	d. Discount Factor	e. Discounted Cost
	R&D	Investment				
9. TOTALS						

10a. Total Project Cost (discounted) ________
10b. Uniform Annual Cost (without terminal value) ________

11. Less Terminal Value (discounted) ________
12a. Net Total Project Cost (discounted) ________
12b. Uniform Annual Cost (with terminal value) ________

TYPE II ECONOMIC ANALYSIS
SUMMARY OF COSTS
FORMAT A-1

13. Source/Derivation of Cost Estimates: (Use as much space as required) All cost estimates are in FY 19__ constant dollars.

a. Non-Recurring Costs:

(1) Research & Development:

(2) Investment:

b. Recurring Cost(s):

c. Net Terminal Value:

d. Other Considerations:

14. Name & Title of Principal Action Officer	Date

TYPE I ECONOMIC ANALYSIS
SUMMARY OF COSTS
FORMAT A-1

1. Submitting Department of the Navy Component: ______________________

2. Date of Submission: ______________________

3. Project Title: ______________________

4. Description of Project Objective: ______________________

____

5a. Present Alternative: ____________ 6a. Economic Life: ____________

b. Proposed Alternative: ____________ b. Economic Life: ____________

7. Project Year(s)	8. Recurring Annual (Operations) Costs		9. Differential Cost	10. Discount Factor	11. Discounted Differential Cost
	a. Present Alternative	b. Proposed Alternative			
12. TOTALS					

TYPE I ECONOMIC ANALYSIS
SUMMARY OF COSTS
FORMAT A-1

13. Present Value of New Investment:

   a. Land and buildings ______________
   b. Equipment ______________
   c. Other (identify nature) ______________
   d. Working Capital (Change: plus or minus) ______________

14. Total Present Value of New Investment (i.e., Funding Requirements). ______________

15. Plus: Present Value of Existing Assets to be Employed on the Project. ______________

16. Less: Present Value of Existing Assets Replaced. ______________

17. Less: Present Value of Terminal Value of New Investment. ______________

18. Total Present Value of Net Investment: $______________

19. Present Value of Life Cycle Cost Savings from Operations (Col. 11) ______________

20. Plus: Present Value of the Cost of Refurbishment or Modifications Eliminated. ______________

21. Total Present Value of Savings. $______________

22. Savings/Investment Ratio (Line 21 divided by Line 18) ______________

23. Discounted Payback Period. ______________

TYPE I ECONOMIC ANALYSIS
SUMMARY OF COSTS
FORMAT A-1

24. Source/Derivation of Cost Estimates: (Use as much space as required). All cost estimates are in FY 19__ constant dollars.

a. Investment Costs: (Itemize Project Costs)

(1) Changes in Working Capital

(2) Net Terminal Value

b. Recurring Costs (Operations):

(1) Personnel

(2) O&M

(3) Overhead Costs

c. Other Considerations:

25. Name & Title of Principal Action Officer	Date

SUMMARY OF OUTPUTS FOR ECONOMIC ANALYSIS
FORMAT B

1. Submitting Department of the Navy Component: ____________________

2. Date of Submission: ____________________

3. Project Title: ____________________

4. Description of Project Objective: ____________________

____

5. Alternative: ____________________

6. Economic Life: ____________________

7. Outputs:

   a. Expected Benefits, Outputs, and Indicators of Effectiveness: (Describe and justify)

   b. Nonquantifiable Benefits: (Describe and justify)

   c. Present Value of Revenues: (Describe and justify)

SUMMARY OF OUTPUTS FOR ECONOMIC ANALYSIS
FORMAT B

8. Source/Derivation of Outputs: (Use as much space as required)

a. Benefits, Performance and Indicators of Effectiveness:

b. Nonquantifiable Benefits:

c. Revenues:

9. Name & Title of Principal Action Officer	Date

INFEASIBLE ALTERNATIVES
FORMAT C

(This format is provided as a guide to the type of documentation that the submitting Navy activity should provide as part of a facility study in the rare situation in which only one method of satisfying a facilities deficiency exists, as required by NAVFACINST 11010.32.)

1. Submitting Department of the Navy Component: ____________________

2. Date of Submission: ____________________

3. Project Title: ____________________

4. Description of Project Objective: ____________________

____

5. Alternatives Investigated:	6. Respective Alternative is infeasible because:
a. ____________	a. ____________
b. ____________	b. ____________
c. ____________	c. ____________
d. ____________	d. ____________
e. ____________	e. ____________
f. ____________	f. ____________

7. Name & Title of Principal Action Officer	Date

APPENDIX E

PRESENT VALUE TABLES AND FORMULAE

PROJECT YEAR DISCOUNT FACTORS

Project Year	Table A PRESENT VALUE OF $1 (Single Amount--to be used when cash flows accrue in varying amounts each year) 10%	Table B PRESENT VALUE OF $1 (Cumulative Uniform Series--to be used when cash flows accrue in the same amount each year) 10%
1	0.954	0.954
2	0.867	1.821
3	0.788	2.609
4	0.717	3.326
5	0.652	3.977
6	0.592	4.570
7	0.538	5.108
8	0.489	5.597
9	0.445	6.042
10	0.405	6.447
11	0.368	6.815
12	0.334	7.149
13	0.304	7.453
14	0.276	7.729
15	0.251	7.980
16	0.228	8.209
17	0.208	8.416
18	0.189	8.605
19	0.172	8.777
20	0.156	8.933
21	0.142	9.074
22	0.129	9.203
23	0.117	9.320
24	0.107	9.427
25	0.097	9.524
26	0.088	9.612
27	0.080	9.692
28	0.073	9.765
29	0.066	9.831
30	0.060	9.891

NOTE: Table A factors are based on continous compounding at a 10% effective annual discount rate, assuming uniform cash flows throughout stated one year periods. Table A factors are approximated by an arithmetic average of beginning and end of year single amount factors found in standard present value tables. Table B factors represent the cumulative sum of Table A factors through any given project year. Formulae for these factors are provided in the last section of this appendix.

Present Value of a Single Amount

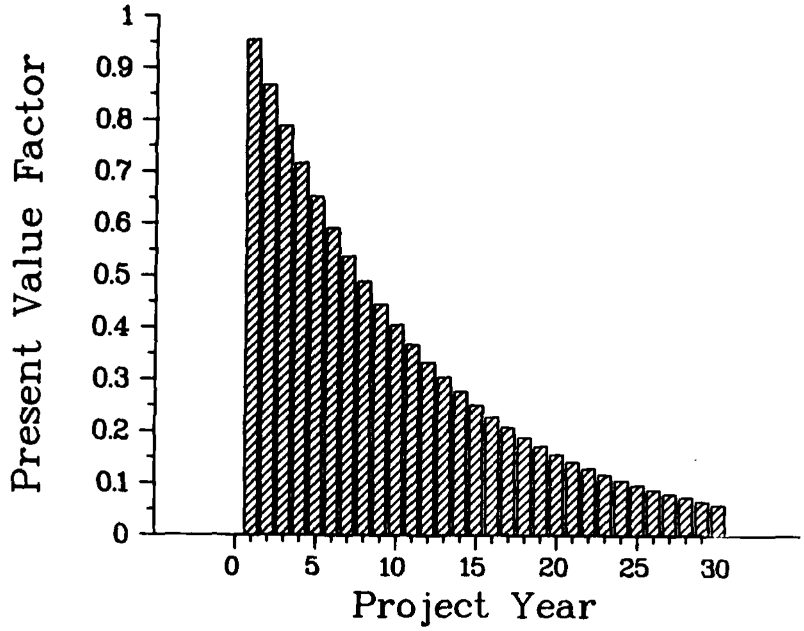

Table A factors are graphed in the bar chart above. Note that costs or benefits occurring many years from today are heavily discounted. It is for this reason that the results of economic analyses of facilities are usually insensitive to assumptions about terminal value.

Table B factors are graphed in the bar chart below. Note that the cumulative present value of a uniform series of costs gradually levels off as the number of years becomes large. Due to this effect of discounting at 10%, assumption of an economic life in excess of 25 years generally does not have a significant impact on the present value of life cycle costs.

Cumulative Uniform Series Factors

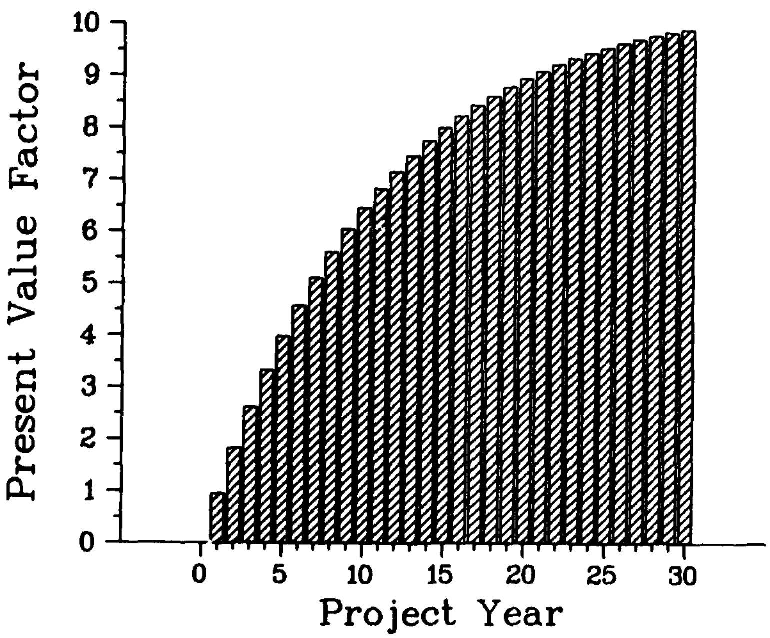

Table C

CONVERSION TABLE
SAVINGS/INVESTMENT RATIO TO DISCOUNTED PAYBACK PERIOD

(Discount Rate = 10%)

DISCOUNTED PAYBACK PERIOD (YRS.) FOR ECONOMIC LIFE SHOWN

SIR	5	10	15	20	25
1.0	5.00	10.00	15.00	20.00	25.00
1.1	4.43	8.58	12.34	15.60	18.30
1.2	3.98	7.53	10.54	12.97	14.82
1.3	3.62	6.71	9.23	11.16	12.57
1.4	3.31	6.06	8.22	9.83	10.97
1.5	3.06	5.53	7.42	8.80	9.75
1.6	2.84	5.08	6.77	7.97	8.79
1.7	2.65	4.71	6.22	7.29	8.01
1.8	2.48	4.38	5.76	6.72	7.36
1.9	2.33	4.10	5.37	6.24	6.82
2.0	2.20	3.85	5.02	5.82	6.35
2.1	2.09	3.63	4.72	5.45	5.94
2.2	1.98	3.44	4.45	5.13	5.58
2.3	1.89	3.26	4.21	4.85	5.27
2.4	1.80	3.10	4.00	4.60	4.99
2.5	1.73	2.96	3.81	4.37	4.73
2.6	1.66	2.83	3.63	4.16	4.51
2.7	1.59	3.71	3.47	3.97	4.30
2.8	1.53	2.60	3.33	3.80	4.11
2.9	1.47	2.50	3.19	3.65	3.94
3.0	1.42	2.40	3.07	3.50	3.78
3.1	1.37	2.32	2.95	3.37	3.63
3.2	1.32	2.24	2.85	3.24	3.50
3.3	1.28	2.16	2.75	3.13	3.37
3.4	1.24	2.09	2.66	3.02	3.26
3.5	1.20	2.03	2.57	2.92	3.15
3.6	1.17	1.96	2.49	2.83	3.05
3.7	1.13	1.91	2.41	2.74	2.95
3.8	1.10	1.85	2.34	2.66	2.86
3.9	1.07	1.80	2.28	2.58	2.78
4.0	1.04	1.75	2.21	2.51	2.70
4.5	.92	1.54	1.92	2.20	2.36
5.0	.83	1.38	1.73	1.96	2.10
5.5	.75	1.24	1.56	1.76	1.89
6.0	.68	1.13	1.42	1.61	1.72
6.5	.63	1.04	1.31	1.47	1.58
7.0	.58	.96	1.21	1.36	1.46
7.5	.54	.90	1.12	1.26	1.35
8.0	.51	.84	1.05	1.18	1.26

NOTE: This table should be used only when savings accumulate in equal amounts each year and there is no significant lead time between the initial investment and the beginning of the savings stream.

PRESENT VALUE FORMULAE

Project Year 10% Discount Factors

Table A Single Amount Factor:

$$a_n = \frac{e^r - 1}{re^{nr}} = \frac{0.1}{r(1.1)^n}$$

Table B Cumulative Uniform Series Factor:

$$b_n = \frac{e^{nr} - 1}{re^{nr}} = \frac{(1.1)^n - 1}{r(1.1)^n}$$

where:

n = the number of years,

e = 2.718281828459...,
the base of the natural logarithms,

$r = \ln(1 + R) = \ln(1.1) = 0.09531018...$, and

R = 0.10, the effective annual discount rate.

(See Appendix F for discount factor formulae which include computation of the effects of differential escalation assumed at a single rate throughout the project life.)

Payback Period

Discounted payback occurs when the present value of accumulated savings equal the present value of the investment. For an investment at time point zero which produces uniform annually recurring savings with no significant lead time between investment and the start of savings, this occurs when

$$I = S \cdot b_n$$

where:

I = the investment,

S = the annual savings,

b_n = the Table B factor for n years, and

n = the number of years to discounted payback.

Substituting the expression for the Table B factor from the previous subsection gives:

$$I = S \left[\frac{e^{nr} - 1}{re^{nr}} \right]$$

Rearranging terms leads to:

$$\frac{rI}{S} = \frac{e^{nr} - 1}{e^{nr}} = \frac{e^{nr}}{e^{nr}} - \frac{1}{e^{nr}} = 1 - \frac{1}{e^{nr}}$$

or

$$\frac{1}{e^{nr}} = 1 - \frac{rI}{S}$$

Then, taking the natural logarithm of both sides of the equation, we have:

$$\ln \left[e^{-nr} \right] = \ln \left[1 - \frac{rI}{S} \right]$$

$$-nr \ln e = \ln \left[1 - \frac{rI}{S} \right]$$

$$-nr = \ln \left[1 - \frac{rI}{S} \right]$$

$$n = \frac{-\ln \left[1 - \frac{rI}{S} \right]}{r}$$

Since $r = \ln(1 + R) = \ln(1.1) = 0.09531018$,

$$n = \frac{-\ln \left[1 - \frac{(0.09531018)I}{S} \right]}{0.09531018}$$

Payback Period - With Lead Time

By a process similar to that in the preceding subsection, the formula for discounted payback with lead time may be derived, starting from

$$I = S(b_n - b_m)$$

where m is the number of years between the investment and the start of savings. The resulting formula is:

$$n = \frac{-\ln\left[\frac{1}{(1.1)^m} - \frac{(0.09531018)I}{S}\right]}{0.09531018}$$

Payback Period - As a Function of SIR and Economic Life

The discounted payback period as a function of savings/investment ratio and economic life may be computed, for the case in which there is no significant lead time and uniform annually recurring savings are produced, by using the relationship

$$SIR = \frac{S \cdot b_e}{I}$$

where b_e is the Table B factor for the economic life and the terms S and I are defined above.

Rearranging terms leads to:

$$\frac{I}{S} = \frac{b_e}{SIR}$$

The right hand side of this equation may be substituted for the I/S term in the formula for discounted payback with no lead time in order to duplicate or extend Table C.

APPENDIX F

DIFFERENTIAL ESCALATION-DISCOUNT FACTORS

NOTE: In these tables the single amount factors are to be applied to one-time costs occurring in isolated years. Cumulative uniform series factors are to be applied to annually recurrent cash flows that are identical in terms of base year prices. These factors assume a single differential escalation rate throughout the project life. For sources of differential escalation-discount rates to be applied to energy costs, refer to Appendix B.

SINGLE AMOUNT

PROJECT YEAR DIFFERENTIAL ESCALATION-DISCOUNT FACTORS

Discount Rate = 10%

Project Year	Differential Escalation Rate				
	-5%	-4%	-3%	-2%	-1%
1	0.933	0.937	0.941	0.945	0.950
2	0.812	0.822	0.833	0.844	0.855
3	0.706	0.721	0.737	0.754	0.771
4	0.614	0.633	0.652	0.673	0.694
5	0.534	0.555	0.577	0.601	0.626
6	0.464	0.487	0.511	0.536	0.564
7	0.403	0.427	0.452	0.479	0.508
8	0.351	0.374	0.400	0.428	0.457
9	0.305	0.329	0.354	0.382	0.412
10	0.265	0.288	0.313	0.341	0.371
11	0.231	0.253	0.277	0.304	0.334
12	0.201	0.222	0.245	0.272	0.301
13	0.174	0.195	0.217	0.243	0.271
14	0.152	0.171	0.192	0.217	0.245
15	0.132	0.150	0.170	0.193	0.220
16	0.115	0.131	0.151	0.173	0.198
17	0.100	0.115	0.133	0.154	0.179
18	0.087	0.101	0.118	0.137	0.161
19	0.075	0.089	0.104	0.123	0.145
20	0.066	0.078	0.092	0.110	0.131
21	0.057	0.068	0.082	0.098	0.118
22	0.050	0.060	0.073	0.088	0.106
23	0.043	0.052	0.064	0.078	0.096
24	0.037	0.046	0.057	0.070	0.086
25	0.033	0.040	0.050	0.062	0.078
26	0.028	0.035	0.044	0.056	0.070
27	0.025	0.031	0.039	0.050	0.063
28	0.021	0.027	0.035	0.044	0.057
29	0.019	0.024	0.031	0.040	0.051
30	0.016	0.021	0.027	0.035	0.046

The above factors are to be applied to cost elements which are anticipated to escalate at a rate slower than general price levels.

SINGLE AMOUNT

PROJECT YEAR DIFFERENTIAL ESCALATION-DISCOUNT FACTORS

Discount Rate = 10%

Project Year	Differential Escalation Rate				
	+1%	+2%	+3%	+4%	+5%
1	0.959	0.963	0.968	0.972	0.977
2	0.880	0.893	0.906	0.919	0.933
3	0.808	0.828	0.849	0.869	0.890
4	0.742	0.768	0.795	0.822	0.850
5	0.681	0.712	0.744	0.777	0.811
6	0.623	0.660	0.697	0.735	0.774
7	0.574	0.612	0.652	0.695	0.739
8	0.527	0.568	0.611	0.657	0.706
9	0.484	0.526	0.572	0.621	0.673
10	0.445	0.488	0.536	0.587	0.643
11	0.408	0.453	0.501	0.555	0.614
12	0.375	0.420	0.470	0.525	0.586
13	0.344	0.389	0.440	0.496	0.559
14	0.316	0.361	0.412	0.469	0.534
15	0.290	0.335	0.386	0.443	0.509
16	0.266	0.310	0.361	0.419	0.486
17	0.245	0.288	0.338	0.396	0.464
18	0.225	0.267	0.316	0.375	0.443
19	0.206	0.247	0.296	0.354	0.423
20	0.189	0.229	0.277	0.335	0.404
21	0.174	0.213	0.260	0.317	0.385
22	0.160	0.197	0.243	0.299	0.368
23	0.147	0.183	0.228	0.283	0.351
24	0.135	0.170	0.213	0.268	0.335
25	0.124	0.157	0.200	0.253	0.320
26	0.113	0.146	0.187	0.239	0.305
27	0.104	0.135	0.175	0.226	0.292
28	0.096	0.125	0.164	0.214	0.278
29	0.088	0.116	0.154	0.202	0.266
30	0.081	0.108	0.144	0.191	0.254

The above factors are to be applied to cost elements which are anticipated to escalate at a rate faster than general price levels.

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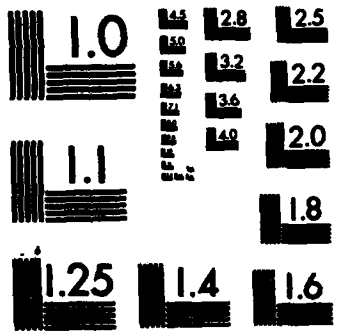

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SINGLE AMOUNT

PROJECT YEAR DIFFERENTIAL ESCALATION-DISCOUNT FACTORS

Discount Rate = 10%

Project Year	Differential Escalation Rate				
	+6%	+7%	+8%	+9%	+10%
1	0.982	0.986	0.991	0.995	1.000
2	0.946	0.959	0.973	0.986	1.000
3	0.912	0.933	0.955	0.977	1.000
4	0.878	0.908	0.938	0.969	1.000
5	0.847	0.883	0.921	0.960	1.000
6	0.816	0.859	0.904	0.951	1.000
7	0.786	0.836	0.888	0.942	1.000
8	0.757	0.813	0.871	0.934	1.000
9	0.730	0.791	0.856	0.925	1.000
10	0.703	0.769	0.840	0.917	1.000
11	0.678	0.748	0.825	0.909	1.000
12	0.653	0.728	0.810	0.900	1.000
13	0.629	0.708	0.795	0.892	1.000
14	0.607	0.688	0.781	0.884	1.000
15	0.584	0.670	0.766	0.876	1.000
16	0.563	0.651	0.752	0.868	1.000
17	0.543	0.634	0.739	0.860	1.000
18	0.523	0.616	0.725	0.852	1.000
19	0.504	0.600	0.712	0.845	1.000
20	0.486	0.583	0.699	0.837	1.000
21	0.468	0.567	0.687	0.829	1.000
22	0.451	0.552	0.674	0.822	1.000
23	0.435	0.537	0.662	0.814	1.000
24	0.419	0.522	0.650	0.807	1.000
25	0.404	0.508	0.638	0.800	1.000
26	0.389	0.494	0.626	0.792	1.000
27	0.375	0.481	0.615	0.785	1.000
28	0.361	0.467	0.604	0.778	1.000
29	0.348	0.455	0.593	0.771	1.000
30	0.335	0.442	0.582	0.764	1.000

The above factors are to be applied to cost elements which are anticipated to escalate at a rate faster than general price levels.

CUMULATIVE UNIFORM SERIES

PROJECT YEAR DIFFERENTIAL ESCALATION-DISCOUNT FACTORS

Discount Rate = 10%

Project Year	Differential Escalation Rate				
	-5%	-4%	-3%	-2%	-1%
1	0.933	0.937	0.941	0.945	0.950
2	1.745	1.759	1.774	1.790	1.805
3	2.450	2.481	2.511	2.543	2.576
4	3.064	3.113	3.164	3.216	3.270
5	3.598	3.668	3.741	3.817	3.896
6	4.062	4.155	4.252	4.353	4.459
7	4.465	4.582	4.704	4.832	4.967
8	4.816	4.956	5.104	5.260	5.424
9	5.121	5.285	5.458	5.642	5.836
10	5.386	5.573	5.772	5.983	6.207
11	5.617	5.826	6.049	6.287	6.542
12	5.818	6.048	6.294	6.559	6.843
13	5.992	6.242	6.512	6.802	7.115
14	6.144	6.413	6.704	7.018	7.359
15	6.276	6.563	6.874	7.212	7.579
16	6.390	6.694	7.024	7.385	7.778
17	6.490	6.809	7.158	7.539	7.957
18	6.577	6.910	7.275	7.676	8.118
19	6.652	6.999	7.380	7.799	8.263
20	6.718	7.077	7.472	7.909	8.394
21	6.775	7.145	7.554	8.007	8.511
22	6.824	7.205	7.626	8.095	8.618
23	6.868	7.257	7.690	8.173	8.713
24	6.905	7.303	7.747	8.243	8.799
25	6.938	7.344	7.797	8.305	8.877
26	6.966	7.379	7.841	8.360	8.947
27	6.991	7.410	7.880	8.410	9.010
28	7.012	7.437	7.915	8.454	9.066
29	7.031	7.461	7.946	8.494	9.118
30	7.047	7.482	7.973	8.529	9.164

The above factors are to be applied to cost elements which are anticipated to escalate at a rate slower than general price levels.

CUMULATIVE UNIFORM SERIES

PROJECT YEAR DIFFERENTIAL ESCALATION-DISCOUNT FACTORS

Discount Rate = 10%

Project Year	Differential Escalation Rate				
	+1%	+2%	+3%	+4%	+5%
1	0.959	0.963	0.968	0.972	0.977
2	1.839	1.856	1.874	1.892	1.910
3	2.647	2.684	2.723	2.761	2.800
4	3.389	3.452	3.517	3.583	3.650
5	4.070	4.165	4.261	4.360	4.461
6	4.695	4.825	4.958	5.095	5.235
7	5.270	5.437	5.610	5.789	5.974
8	5.797	6.005	6.221	6.446	6.680
9	6.281	6.531	6.793	7.067	7.353
10	6.726	7.020	7.329	7.654	7.996
11	7.134	7.472	7.830	8.209	8.610
12	7.509	7.892	8.300	8.734	9.196
13	7.853	8.281	8.739	9.230	9.755
14	8.169	8.642	9.151	9.699	10.288
15	8.459	8.977	9.536	10.142	10.798
16	8.726	9.287	9.897	10.561	11.284
17	8.970	9.575	10.235	10.958	11.748
18	9.195	9.842	10.552	11.333	12.191
19	9.401	10.089	10.848	11.687	12.614
20	9.590	10.319	11.126	12.022	13.018
21	9.764	10.531	11.386	12.339	13.403
22	9.924	10.729	11.629	12.638	13.771
23	10.070	10.911	11.857	12.921	14.122
24	10.205	11.081	12.070	13.189	14.458
25	10.328	11.238	12.270	13.442	14.777
26	10.442	11.384	12.457	13.681	15.083
27	10.546	11.519	12.632	13.908	15.374
28	10.642	11.645	12.796	14.121	15.653
29	10.730	11.761	12.950	14.324	15.918
30	10.810	11.869	13.093	14.515	16.172

The above factors are to be applied to cost elements which are anticipated to escalate at a rate faster than general price levels.

CUMULATIVE UNIFORM SERIES

PROJECT YEAR DIFFERENTIAL ESCALATION - DISCOUNT FACTORS

Discount Rate = 10%

Project Year	Differential Escalation Rate +6%	+7%	+8%	+9%	+10%
1	0.982	0.986	0.991	0.995	1.000
2	1.928	1.946	1.964	1.982	2.000
3	2.839	2.879	2.919	2.959	3.000
4	3.718	3.787	3.857	3.928	4.000
5	4.564	4.670	4.777	4.887	5.000
6	5.380	5.529	5.681	5.839	6.000
7	6.166	6.364	6.569	6.781	7.000
8	6.923	7.177	7.440	7.715	8.000
9	7.653	7.968	8.296	8.640	9.000
10	8.357	8.737	9.136	9.557	10.000
11	9.035	9.485	9.961	10.465	11.000
12	9.688	10.212	10.770	11.366	12.000
13	10.317	10.920	11.565	12.258	13.000
14	10.924	11.608	12.346	13.142	14.000
15	11.508	12.278	13.112	14.018	15.000
16	12.071	12.930	13.865	14.886	16.000
17	12.614	13.563	14.603	15.746	17.000
18	13.137	14.180	15.329	16.598	18.000
19	13.641	14.779	16.041	17.443	19.000
20	14.127	15.363	16.740	18.279	20.000
21	14.595	15.930	17.427	19.109	21.000
22	15.046	16.482	18.101	19.930	22.000
23	15.480	17.019	18.762	20.745	23.000
24	15.899	17.541	19.412	21.551	24.000
25	16.303	18.049	20.050	22.351	25.000
26	16.692	18.543	20.676	23.143	26.000
27	17.066	19.023	21.291	23.928	27.000
28	17.427	19.491	21.895	24.706	28.000
29	17.775	19.946	22.488	25.477	29.000
30	18.111	20.388	23.070	26.241	30.000

The above factors are to be applied to cost elements which are anticipated to escalate at a rate faster than general price levels.

DIFFERENTIAL ESCALATION-DISCOUNT FACTOR FORMULAE

Project Year Differential Escalation - Discount Factors

Single Amount Factor:

$$a_n = \frac{e^{(r-d)} - 1}{(r-d)\left[e^{n(r-d)}\right]}$$

Cumulative Uniform Series Factor:

$$b_n = \frac{e^{n(r-d)} - 1}{(r-d)\left[e^{n(r-d)}\right]}$$

where:

n = the number of years,

e = 2.718281828459........,
the base of the natural logarithms,

$r = \ln(1+R) = \ln(1.1) = 0.09531018.....,$

R = 0.10, the effective annual discount rate,

$d = \ln(1+D)$, and

D = is the effective annual differential escalation rate.

Payback Period

For cases in which an investment at time point zero produces annually recurring savings that are uniform when valued at base year prices, with no significant lead time between investment and the start of savings, and a single differential escalation rate applies to all savings, the discounted payback period is given by:

$$n = \frac{-\ln\left[1 - \frac{(r-d)\,I}{S}\right]}{(r-d)}$$

where:

n = the number of years to discounted payback,

I = the investment, and

S = the annual savings at base year prices.

APPENDIX G

GLOSSARY OF

ECONOMIC ANALYSIS RELATED

TERMS

This appendix provides definitions of terms, in addition to the terms defined in the main body of the text, which the analyst (or reviewer) may encounter in the course of working on an economic analysis. Many of the definitions have been adapted from the Glossary for Economic Analysis, Program Evaluation and Output Measurement, which was prepared by the Defense Economic Analysis Council (DEAC), and which was adapted from a glossary prepared by the American Association for Budget and Program Analysis (AABPA). Other definitions have been adapted from the Glossary for Systems Analysis and Planning-Programming-Budgeting, prepared by the U.S. General Accounting Office (GAO). Terms explained in the main body of the text may be accessed via the Index (Appendix I).

Glossary of Economic Analysis Related Terms

accounting, accrual- Accounting in which revenues and expenditures are recorded as they are earned or occur without regard to when the income is actually received or when payment is made. Accrual accounting contrasts with cash basis accounting in which cash receipts and disbursements are recorded as they occur during a given period.

a fortiori analysis- A procedure for coping with uncertainty by handicapping the preferred alternative by resolving all questions of uncertainty in favor of some other alternative. If the initially preferred alternative remains acceptable, the case for favoring it has been strengthened.

algorithm- A set of ordered procedures, steps, or rules, usually applied to mathematical procedures, and assumed to lead to the solution of a problem in a finite number of steps.

alternatives- Different ways of reaching the objective or goal. In economic analysis and program analysis objectives and goals are defined so that the consideration of different options or alternatives is not precluded.

amortization- The gradual reduction of the balance in an account according to a specified schedule of time and amounts. Usually the provision for extinguishing a debt, including interest, by means of a sinking fund or other form of payment.

analysis- A systematic approach to problem solving. Complex problems are made simpler by separating them into more understandable elements. Involves the identification of purposes and facts, the statement of defensible assumptions, and the derivation of conclusions therefrom. The different types of analyses are distinguishable more in terms of emphasis than in substance. All are concerned with the decision-making process; most of them apply quantitative methods.

appropriation- The most common form of budget authority. Allows agencies to incur obligations and to make expenditures for specified purposes and in specified amounts. At the Federal level, ordinary current appropriations (either no-year or one or more years) are budget authority granted currently by the U.S. Congress. Does not include contract authority to spend debt receipts.

assets- Property, both real and personal, and other items having monetary value.

assumptions- Judgments concerning unknown factors and the future which are made in analyzing alternative courses of action. For instance, in a sewage disposal problem, a possible assumption is that no new technology would be available in the short run.

asymptote- In terms of graph of a function, an asymptote is a straight line which the graph continually approaches and with which it coincides only at an infinite distance. It represents a boundary or limit which the function never crosses.

authorization- Legislation or other action which sets up a program or activity. May set limits on amounts that can be appropriated subsequently but usually does not provide budget authority. In the Federal Government, an authorization is provided by an Act of U.S. Congress and usually emanates from a specific committee of Congress.

average- A quantity or value which is representative of the magnitude of a set (usually a population or a sample) of quantities or values related to a common subject. Popularly refers to arithmetic mean. There are different types of averages and their application varies with the problem involved.

base period- The time period selected to determine the base values of variables (ratios, quantities, or values) for use in current planning and programming. Also, the time period to which index numbers relate. For example, the base year used as the base period of a price index, such as the Consumer Price Index (CPI).

Bayesian statistics- A school of thought within statistics in which estimates of probabilities of events are based on the scientist's or decisionmaker's subjective beliefs as modified by empirical data. In classical statistics, probability estimates are based solely on objective data. A consequence of this difference is that Bayesian statistics is considered more decision-oriented than classical statistics since the point of "enough information" for a decision is reached more quickly under Bayesian statistics. An additional aspect of the Bayesian approach which makes it more decision-oriented is that it explicitly takes into account the cost of obtaining additional data.

benefit- Result attainment in terms of the goal or objective of output. For example, if the goal of an educational program is 100 percent literacy for a target group within 10 years, a measure of the benefit attributable to that program would be the increase in the percentage of literacy in the group rather than the number of trainees or any other measure of output.

benefit analysis- Analysis to identify, measure, and evaluate the benefits for each proposed alternative. Sometimes termed benefit determination.

benefit/cost analysis- See: Cost/benefit analysis.

benefit, direct- Result attained which is closely related with the project/program in a cause and effect relationship. For example, increase in literacy as a result of a reading program.

benefit, indirect- Result attainment circuitously related to the program. For example, decrease in crime due to increased literacy arising from a reading program. See: Externalities.

benefit, principal- Result attained toward accomplishing the major goals or objectives of a program. For example, increases in employment rates and income per capita could be the principal benefits derived from an increase in literacy resulting from a reading program.

benefit, secondary- See: Externalities.

benefit, social- Result attained for society as a whole. Benefits which accrue to society as a result of a public program which may or may not be conducted primarily for the benefit of those who are required to act under the program. For example, the reduced cleaning costs to household incident to the installation of an air pollution control system required by Government regulation. Sometimes expressed in terms of aesthetic, recreational, and intellectual benefits. For example: increase in library usage and theater attendance due to increased literacy as a result of a reading program. See: Externalities.

benefit, subsidiary- Result attained toward lower priority objectives or goals of the program. For example, decrease in welfare roles would be a subsidiary benefit as newly literate population becomes employable.

bias- An effect which deprives a statistical result of representativeness by systematically distorting it. Bias may originate from poor design of the sample, from deficiencies in carrying out the sampling process, or from an inherent characteristic of the estimating technique used. Also a survey questionnaire could be biased if it allows only the responses desired by the questioner. Often the degree of bias related to an estimating technique may be so small as to be of no practical importance but in other instances significant enough to invalidate the usefulness of the analysis.

budget estimate- Documentation regarding resources required. The budget estimate represents a plan relating to purpose, size, scope and priorities of operations during the budget period.

budget, program- A budget based on objectives and outputs and coordinated with planning. Focuses upon results of programs by linking resources to purposes for several years ahead, emphasizing policy implications of budgeting. Also refers to line item in any budget document covering the budget request for a program element.

capital- Assets of a permanent character having continuing value. Examples are land, buildings, and other facilities including equipment. Also, the non-expendable funds used to finance an enterprise or activity. Sometimes refers to the excess of assets over liabilities.

cash flow, discounted- See: Discounted cash flow.

cash recovery period- See: Payback period.

coefficient- A number written before a quantity to indicate multiplication, that is how many times the quantity is to be taken additively. For example, in the expression 5 ax the coefficient of the quantity ax is 5 while the coefficient of the quantity x is 5a.

combinations and permutations- In mathematics and statistics, a combination is a group of several things or symbols in which the order of arrangement is immaterial. A permutation is an arrangement reflecting a change in order or sequence, especially the making of all possible changes. Thus, when a problem concerns groups without any reference to order within the group, it is a problem in combinations. When the problem requires that arrangements to be taken into account, it is a problem in permutations. Example: the group of letters ABC make a single combination, whatever their order, but make six permutations, viz. ABC, ACB, BCA, BAC, CAB, CBA.

confidence level- Quantitative statement of the assurance or confidence used in making an estimate from the sample. Usually expressed as a percentage; it is the number of times out of 100 that the true answer would be found within the determined confidence interval. For instance, with a 90% confidence level, we say that we have 90% assurance (or 9 times out of 10) that the estimated expense of $20,000 is within ± $6000 (the confidence interval) of the true amount allowed for expenses. With increases in the confidence level, the confidence interval must be widened and this decreases information regarding the estimated quantity. Therefore, in selecting the confidence level, much depends on the specific problem as well as judgments about the risks associated with an estimate which misses the true value by more than the amount of the confidence interval.

constant dollars- Computed values which remove the effect of price changes over time. Derived by dividing current dollar values by their corresponding price indexes based on a time period specified as 100. The result is a series as it would presumably exist if prices were the same over time as in the base year; in other words, as if the dollar had constant purchasing power. Thus changes in such a series of price-adjusted output values would reflect only changes in the real volume of output.

constraints- Limitations of any kind to be considered in planning, programming, scheduling, implementing or evaluating programs.

consumer's surplus- In economics, the difference between the price that a consumer pays for a good or a service and the amount that he would be willing to pay rather than be deprived of the good or service.

contingency analysis- A technique for exploring the possible effects of errors in major assumptions. It is designed to cope with significant uncertainties of a quantitative nature. The procedure is to vary the assumptions regarding important aspects of the problem and examine the

changes in results of the analysis due to these changes in the assumptions. For example, in an analysis designed to disclose a preferable military strategy among several alternatives, the assumption that one of our major allies becomes allied with our potential enemies might be made to explore the effects of such a contingency. See: Sensitivity analysis.

cost- The value of things used up or expended in producing a good or a service. Also whatever must be given up in order to adopt a course of action.

cost, actual- Cost incurred in fact as opposed to "standard" or projected costs. May include estimates based on necessary assumptions and prorations concerning outlays previously made. Excludes projections of future outlays.

cost allocation- The portion of joint or indirect assets assigned to a particular objective such as a job, a service, a project, or a program.

cost analysis- Determining the actual or estimated costs of relevant spending options. An integral part of economic analysis and program analysis. Its purpose is to translate the real resource requirements (equipment, personnel, etc.) associated with alternatives into estimated dollar costs. The translation produces direct one-dimensional cost comparisons among alternatives.

cost, applied- The value of goods and services used, consumed, given away or lost by an agency during a given period regardless of when ordered, received or paid for. Generally, applied costs are related to program outputs so that such costs become the financial measures of resources consumed or applied in accomplishing a specific purpose. For operating programs, such costs are related to the value of resources consumed or used; for procurement and manufacturing programs, they are related to the value of material received or produced; for capital outlays, they are related to the value of assets put in place; for loan activities, they are related to assets required.

cost, average- The quotient of total cost divided by corresponding output. Also, the sum of average fixed cost per unit of output plus average variable cost per unit of the same output.

cost/benefit- A criterion for comparing programs and alternatives when benefits can be valued in dollars. Refers to the ratio, dollar value of benefit divided by cost. Provides comparisons between programs as well as alternative methods. Useful in the search for an optimal program mix which produces the greatest number of benefits over costs. See: Cost effective alternative; Present value.

cost/benefit analysis- Comparing present values of all benefits divided by those of related costs, where benefits can be valued in dollars the same way as costs in order to select the alternative which maximizes the present

value of the net benefit of the alternative or program, and to select the best combination of alternatives or programs using the benefit/cost ratio. See: Cost effective alternative.

cost, direct- Any cost which is identified specifically with a particular final cost objective or goal. Varies with level of operation.

cost effective alternative- That alternative which. . . (1) Maximizes benefits and outputs when costs for each alternative are equal (the most effective alternative); or (2) Minimizes costs when benefits and outputs are equal for each alternative (the most efficient alternative); or (3) Maximizes differential output per dollar difference when costs and benefits of all alternatives are unequal.

cost elements- Cost projected for expected transactions, based upon information available. Does not pertain to estimates of costs already incurred. See: Cost, actual.

cost estimating relationship (CER)- a numerical expression of the link between a characteristic, a resource, or an activity and a particular cost associated with it. The expression may be a simple average, percentage, or complex equation derived by regression anlysis which relates cost (dependent variable) to physical and performance characteristics (independent variable). For example, estimated costs of an aircraft airframe (dependent variable) might be determined, using regression analysis, to be a function of airframe weight, delivery rates, and speed (independent variables). The CER shows how the values of such independent variables are converted into estimated costs.

cost, fixed- Cost incurred whether or not any quantity of an item is produced. Does not fluctuate with variable outputs. For example, the rental cost for a manufacturing facility might be treated as fixed cost because it does not vary with output.

cost, imputed- A cost that does not appear in accounting records and does not entail dollar outlays.

cost, incremental- Increase in costs per unit increase in program activity. Also the additional cost needed to make a change in the level or nature of output. If incremental cost per ton is $100 for an increase in production from 100 to 150 tons per month but only $75 per ton for an increase in input to 200 tons per month, the incremental cost in total operations would be $5000 for adding 50 tons of output and only $7500 for adding 100 tons per month.

cost, indirect- Any cost, incurred for joint objectives, and therefore not usually identified with a single final cost objective. Includes overhead and other fixed costs and categories of resources other than direct costs, required to add up all segments of total cost. For example, the cost of bookkeeping is often not identified with a single type of output.

cost, induced- All uncompensated adverse effects caused by the construction and operation of a project or program, whether tangible or intangible. For example, deterioration in environmental quality resulting from a water resource project. See: Externalities.

cost, joint- Cost of producing two or more outputs by a single process.

cost, marginal- Change in total cost due to a change in one unit of output. It is a special case of the more general term, incremental cost. Theoretically, a firm will maximize profits (or minimize losses) by increasing output until marginal cost equals marginal revenue. At that point, any additional output will incur a cost greater than the added revenue and any reduction in output will reduce revenue by more than the reduction in costs.

cost, opportunity- The benefits that could have been obtained by the best alternative use of resources which have been committed to a particular use. The measurable sacrifice foregone by forsaking an alternative investment.

cost, social- The total costs of an activity both public and private. For example, health effects of auto pollution are a component of the social cost of automobile transportation.

cost, standard- A predetermined cost criterion. A basis for pricing outputs, evaluating perforamnce, and preparing budgets. May be expressed as unit cost for an item or a component, or total cost for a process, a project, or a program.

cost, sunk- Non-recoverable resource that has been consumed as the result of a prior decision. Sunk costs are not altered by a change in the level or nature of an activity and have no bearing on current investment decisions.

costs, total- Sum of fixed and variable costs at each level of output during a specified time period.

cost, undistributed- Costs incurred but not allocable to specific projects or programs, such as overhead costs for staff personnel working on serveral projects or programs.

cost, unit- Cost of any type per unit of output.

cost, variable- Cost that varies with the quantity of output produced.

criteria- The standards against which evaluations are performed. Measures used should capture or embrace as closely a possible the purposes sought. May consist of proxy measures for dimensions difficult to measure. For example, a school system may seek to develop the maximum potential of all students. Unable to measure potentials, we may use proxy measures such as

number of students graduated from high school and the scores made on standardized tests or any other tests that provide a significant basis for the comparison of program results or policies.

critical path method (CPM and PERT)- CPM (Critical Path Method) and PERT (Program Evaluation and Review Technique) are activity network models. In the network representation, the nodes usually depict events (material received, foundation completed, foundation inspected, etc.) and the arcs depict activities (order materials, construct foundation, inspect foundation, etc.). CPM seeks to determine the expected time of completion of the total project and times of completion of the subprojects of which it is composed. PERT goes further and seeks to estimate variances associated with these expected times of completion.

data- Numeric information or evidence of any kind.

decision theory- A body of knowledge and related mathematical techniques developed from the fields of mathematics, statistics, and logic which are designed to aid in making decisions under conditions of uncertainty. Decision theory is similar to game theory in several respects; however, a major difference between the two is that in game theory the decision is being made vis-a-vis an opponent, whereas in decision theory the only opponent is nature with its related uncertainty. Often decisions are analyzed through construction of a decision tree, analyzing the possibilities at any one time and, if possible, the probability for each. Each node of the decision tree represents an event and each branch represents an alternative course of action. Associated with each alternative course is a result or payoff of some sort.

degree of freedom- Refers to the size of a sample, which is labeled "n," less the number of parameter estimates "used up" in the process of arriving at a given unbiased estimate. For example, to estimate the mean needed to calculate the variance of a population, it is necessary to use the mean of the sample, thus using up one degree of freedom. The estimate of the population variance would thus have n-1 degrees of freedom.

delphi method- Technique for applying the informed judgment of a group of experts, using a carefully planned program of sequential individual interrogations, without direct confrontation, and with maximum use of feedback of digested information in the investigation and solution of problems. It is a form of cybernetic arbitration having three features: anonymity, controlled feedback and statistical group response. A way of improving the panel or committee approach by subjecting the views of the individual experts to each others' criticism in ways that avoid face to face confrontation, preserving anonymity of opinions and achieving a consensus rather than a compromise. Usually consists of a series of repeated interrogations by means of questionnaires. After the initial interrogation of each individual, each subsequent interrogation is supplemented by information from the preceding round of replies. The expert is encouraged to reconsider and, as appropriate, change or defend the previous reply in light of the replies of other members of the group.

demand- Usually means "demand schedule" which is the relationship between price and quantity demanded. The demand schedule expresses how much of the good or service would be bought at various prices at a particular point in time. Sometimes changes in the quantity demanded are confused with changes or shifts in the demand schedule. A shift in the demand schedule may mean, for example, that consumers will demand more of the good or service at all possible prices than they would have previously demanded at the same prices. On the other hand, an increase in the quantity demanded would result only by decreasing the price of the good or service.

depreciation- A reduction in the value of an asset estimted to have accrued during an accounting period due to age, wear, usage, obsolescence, or the effects of natural elements such as decay or corrosion.

diminishing marginal utility- The principle that, as the level of consumption of a good is increased, a point is reached where each additional unit consumed provides less utility than did the preceding unit.

diminishing returns, law of- The economic principle that, as there is an increase in the quantity of any variable input which is combined with a fixed quantity of other inputs, the increases in marginal physical product (output) generated by the variable input must eventually decline. For example, an increase in fertilizer on a fixed amount of land will lead to diminishing increases in total output until eventually total output will decline.

disbenefit- Undesirable result. An offset against positive benefits.

disbenefit, social- Social diseconomy. Loss of social benefits. For example, problems created by urban renewal projects in dislocating people from their communities. See: Externalities.

disbursements- The dollar amount of checks issued and cash payments made, net of refunds received. Includes all advances of money; excludes transfers involving no expenditures.

discount factor- The multiplier for any specific discount rate which translates expected cost or benefit in any specific future year into its present value.

discounted cash flow- See: Present value.

discount rate- The interest rate used in calculating the present value of expected yearly costs and benefits. Represents the price or opportunity cost of money. See: Present value.

discounting- A computational technique using an interest rate to calculate present value of future benefits and costs. Used in evaluating alternative investment proposals that can be valued in money. Reflects private sector investment opportunity cost as well as preference for current over future dollar incomes.

diseconomy- A damage received as a consequence of the economic activities of another for which the damaged does not receive compensation. See: Disbenefit, social; Externalities.

distributional effects- Impacts on those harmed as well as those benefited by the project/program including the differences in benefits flowing to those receiving them.

econometric model- A set of related equations used to analyze economic data through mathematical and statistical techniques. Depicts quantitative relationships that determine results in terms of economic concepts such as output, income, employment and prices. Such models are used for forecasting, estimating the likely quantitative impact of alternative assumptions, and for testing various propositions about the way the economy works.

econometrics- The mathematical formulation of economic theories and the use of statistical techniques to accept or reject the theories.

economic analysis- A systematic approach to the problem of choosing how to employ scarce resources and an investigation of the full implications of achieving a given objective in the most efficient and effective manner. The determination of efficiency and effectiveness is implicit in the assessment of the cost effectiveness of alternative approaches.

economic efficiency- That mix of alternative factors of production which results in maximum outputs, benefits, or utility for a given cost. Also, that mix of productive factors which represents the minimum cost at which a specified level of output can be obtained.

economic good- An object which is both useful, in the sense that it satisfies a want or need, and relatively scarce. For example, food is both useful and scarce. Air, though useful, is not scarce, and is not an economic good. Poison ivy, though relatively scarce, is not useful, and therefore is not an economic good.

economies of [illegible]- [illegible]eductions in unit cost of output resulting from the production of a[illegible] units. Stems from (1) increased specialization of labor as [illegible] output increses, (2) decreased unit costs of materials, (3) bett[illegible]tilization of management, (4) acquisition of more efficient equipment, and (5) greater use of by-products. For example, the cost of producing a new aircraft, for which the prototype cost $30 million, might be $3 million each for 100 aircraft and only $1 million each for 1,000 aircraft due to economies of scale.

effectiveness- The rate at which progress towards attainment of the goal or objective of a program is achieved. Rate at which the benefits of a program are produced. Effectiveness is not entirely dependent upon the efficiency of a program because program outputs may increase without necessarily increasing effectiveness. Effectiveness is increased by strategies which employ resources to take advantage of changes in unmanageable factors in such a way that the greatest possible advancement of whatever one is seeking is achieved. For example, the effectiveness of an export promotion program may be increased by shifting exhibitions from countries of slow economic growth to countries of more rapid growth to increase the export sales of exhibitors. This improvement might be achieved despite a consequent decrease in efficiency assuming that outputs (number of exhibitions mounted, number of firms exhibiting, number of potential purchasers visiting the shows, etc.) per dollar of costs are reduced due to shifting shows to fewer markets. See: Productivity, Output Measures.

elasticity- A numerical measure of the responsiveness of one variable to changes in another. If greater than one, it indicates that the first variable is relatively elastic to changes in the second (i.e., when the second changes by one percent, the first changes by more than one percent.) If the numerical value of elasticity is equal to one (i.e., unitary elasticity) the first variable is said to be elastic to changes in the second (a one percent change in the second variable will cause a one percent change in the first). In economics, elasticity is a measure of the responsiveness of the quantity demanded or supplied to changes in price. For example, the change in number of bus riders in response to change in bus fares.

endogenous variable- A variable the magnitude of which is dependent on and determined by the model being studied. See also: exogenous variable.

engineering estimate- An estimate of costs or results based on detailed measurements or experiments and specialized knowledge and judgment. Also referred to as engineering method of cost estimating.

evaluation- Appraisal of the effectiveness of a decision made in the past. See: Program evaluation.

exogenous variable- A variable which is wholly independent of the model being studied, that is, a variable determined by outside influences. See also: endogenous variable.

expected value- The summation of the products obtained by multiplying the probability of the occurrence of an outcome times the value of the outcome if it does occur. A decision criterion for appraising the value of payoffs by applying judgmental or factual evidence concerning the probability of such outcomes. For example, assume that a project has a 60 percent chance of succeeding, wherein the government would gain $10,000,000, and a 40 percent chance of failing, wherein the government would lose $8,000,000. The expected value of the project is (.60 x $10,000,000) - (.40 x $8,000,000) = $2,800,000.

expenditures- Generally refers to expenses paid and all other kinds of outlays made during a fiscal period. Sometimes refers to cash disbursements only.

expenditures, accrued- Charges incurred and liabilities established for goods or services received and for other reasons, such as damage claims, benefit payments, and annuities, during a specified period. Expenditures accrue when work is performed or resources delivered regardless of when payment is made or when resources are used. That portion of accrued expenditures which is unpaid at a given time is a liability; that portion of disbursements made for which the expenditures have not accrued (advances and prepayments) is an asset. Federal agences have implemented reporting of accrued expenditures.

externalities- Benefits and costs (economies or diseconomies) that affect parties other than the ones directly involved. Sometimes referred to as spillovers. An external economy is a benefit received by one from an economic activity of another for which the beneficiary cannot be charged. An external diseconomy is a cost borne or damage suffered consequent to the economic activities of others for which the injured is not compensated. For example, a city downstream benefits from, but does not pay for, a water pollution control program instituted upstream.

fiscal policy- The actions and purpose of the federal government respecting economic goals such as high employment, stable growth and prices, and balance of payments equilibrium through changes in taxes and level of government spending. Distinct from monetary policy.

free good- A good or service that is so abundant, in relation to the demand for it, that it can be obtained without exertion or paying money or exchanging another good. For example, air and, in some localities, rainfall.

frequency distribution- A listing, often appearing in the form of a curve on a graph, of the frequency with which possible values of a variable have occurred. For example, it might show that in a group of 100 persons 50 were within the 10 to 25 year-old category, 30 were within the 26 to 50 year-old category, and 20 were within the 51-80 year-old category. Viewed in another way, this frequency distribution would show that the variable "age" assumed a value from 10 to 25 years, 50 times, a value from 26 to 50, 30 times, and so on.

function- A group of related activities and projects for which an organizational unit is responsible. Part of a system. Also, the principal purpose a program is intended to serve. For example, public safety, health protection, surface transportation. Also, a mathematical statement of a rule or relation between variables. For example, in the expression, $y = f(x)$, the variable y is a function of variable x if for every value assigned to x, a specific value of y is determined. Here, x would be the independent variable and y would be the dependent variable.

fund, contingency- Money set aside in a budget to provide for unforeseen requirements.

fund, revolving- A fund established to finance a cycle of operations in which revenues are retained for reuse in a manner that will maintain the principal of the fund. A self-perpetuating or working capital fund.

funding- Providing funds to make payments and/or authority to incur commitments and obligations within established limitations.

game theory- A branch of mathematical analysis developed by von Neumann and Morgenstern to study tactical and decision-making problems in conflict situations. It is a mathematical process of selecting an optimum strategy in the face of an opponent who has a strategy of his own. Optimality may be defined by any of several criteria.

Gross National Product (GNP)- The total national output of final goods and services at market prices for a given period.

heuristic problem solving- Solving problems by the trial and error approach. Frequently involves the act of learning and sometimes leads to further discoveries or conclusions but provides no proof of the correctness or optimality of outcomes.

hypothesis- A theoretical proposition or tentative explanation that is capable of empirical verification.

imputations- Estimates which make possible the inclusion of data for variables which are difficult to measure or do not take measurable monetary form. The general procedure for counting these non-monetary variables is to value them as if they were paid for. For example, the four major imputations made in the U.S. National Income and Product Accounts are for wages and salaries paid in kind (food, clothing, lodging); rental value of owner-occupied houses; food and fuel produced and consumed on farms; and interest payments by financial intermediaries which do not otherwise explicitly enter the accounts.

incommensurables- Consequences of alternatives compared that cannot be translated into the numeric terms being used. For example, the psychological impact on the community of a decision, such as losing a fire station, could not be put into numeric values in. the same manner as increases in losses due to fires.

incremental cost- The cost associated with a change in the level of output. For example, if presently the total cost of production is $100,000 and under a planned increase in volume the total cost would be $125,000, the incremental cost would be $25,000.

index- Statistical device for measuring changes in groups of data and serves as a yardstick of comparative measure, expressed as an index number.

index, consumer price- A measure of average change over time in prices of goods and services purchased by city wage-earners and clerical-worker families and individuals. The items priced on a monthly and quarterly basis of the U.S. consumer price index, for example, included some 400 goods and services in a sample of 56 areas. This index is weighted to account for the difference in the importance of the individual items by use of the Laspeyres formula $\sum P_nQ_0/P_0Q_0 \times 100$, where P_n is the price for each item in the base year and Q_0 is the quantity of each item in the base year.

index number- A number used to measure change by relating a variable in one period to the same variable in another period, known as the base period. The index number is found by dividing the variable by the base period value and multiplying by 100.

indifference curve- A locus of points representing alternative combinations of two variables, often commodities or services to which the consumer is indifferent because each combination is equally as acceptable as another. Each point on the curve yields the same level of total utility to the user. The slope of an indifference curve is known as the marginal rate of substitution (also the substitution ratio and the relative marginal utility ratio) and is significant in analysis of demand.

inflation- Decrease in the value of money due to rising prices.

input- Resources including personnel, funds, and facilities utilized to obtain a specific output.

interval estimate- An estimate which states, subject to a given confidence level, that the characteristic of interest has a value that is located somewhere within a range or interval of values.

investment- An acquisition of a capability or capacity acquired in the expectation of realizing benefits.

iso-cost curve- An indifference curve showing the different combinations of two outputs that can be obtained for a specific cost. All points on the curve represent a single level of cost.

iterative process- A series of computations in a repeating cycle of operations designed to bring the results closer to the desired outcome with each repetition.

learning curve- A curve which describes the set of points conforming to the observed phenomenon that unit cost reductions are a constant percentage decrease for each doubling of the cumulative quantity produced. This means that the cost of manufacturing unit 2 will be a certain percentage less than the cost of manufacturing unit 1; the cost of unit 4 will be the same percentage less than unit 2, and so on.

least-cost alternative- The alternative producing, at less cost, the same or greater quantity of a given output than any other alternative.

life cycle estimates- All anticipated costs, directly and indirectly associated with an alternative during all stages: preoperational, operational, and terminal.

limiting process- As applied to functions in general, it is a basic tool of mathematics that deals with the value approached by a function as its independent variable approaches some fixed value.

linear programming- A mathematical technique which assumes linear relationships (expressible in simultaneous linear equations which may be represented graphically as a straight line) between variables and produces optimal solutions to problems concerning resource allocation and scheduling, subject to one or more limiting constraints. The final output (or cost) to be maximized (or minimized) is called the objective function. In Government agencies, the objective function may be maximization of output or minimization of costs within a time or cost restraint.

macroeconomics- The study of the total or aggregate performance of an economy. It is concerned with concepts such as National Income, Gross National Product, price level, wage increases and level of employment for the economy as a whole.

marginal analysis- Technique for evaluating an added increment. A basis for comparing the added cost to the benefit gained. The term marginal refers to the last increment of whatever is being considered. Profits per unit of cost will be maximized when the additional increment of revenues and additional increment of cost are equal. At any other point, either additional revenue could be obtained at less additional cost, or additional revenue obtained would be less than the additional costs incurred.

marginal cost- In a marginal analysis, the change in total cost due to a one unit change in output. It is a special case of the more general term incremental cost. Theoretically, a purely competitive firm will maximize profits by increasing output until marginal cost equals price, while an imperfectly competitive firm will equate marginal cost to marginal revenue.

marginal revenue- The change in total revenue due to one-unit change in output.

Markov analysis- A method of analyzing the current movement of some variable in an effort to predict the future movement of that same variable. A first-order Markov process is based on the assumption that the probability of the next event depends on the most recent event and not at all on any previous event. A second-order Markov process assumes that the next event depends on the past two events, and so on. A simple example of a first-order Markov process would be a baseball team's performance, if it could be shown that the key to determining the probability of a win is the result of the preceding game. That is, e.g., if the team won its last game the probability of a win today is .6 but if it lost yesterday the probability of a win is .4.

matrix- A rectangular array of rows and columns. Matrices may be subjected to mathematical operations such as multiplication of one by another, addition of two or more, and others. Matrices may be manipulated in total in a manner similar to the algebraic manipulation of single numbers, but knowledge of special rules, called matrix algebra, is necessary for such manipulation. The development of matrix algebra and of computer solution has made possible the efficient solution of very large systems of simultaneous linear equations.

mean, arithmetic- The sum of all the values of a set of observations divided by the number of observations. Also known as an average, or mean. It is an indication of the typical value for a set of observations. Expressed as:

$$M = \sum_{i=1}^{n} \frac{X_i}{n}$$

where M = mean

$\sum_{i=1}^{n}$ is the sum of observations from i = 1 to i = n

Xi = observations
n = number of observations

median- The central value of a set of observations, such as incomes, that have been arranged in order of magnitude. It is that value which divides the set so that an equal number of items are on either side of it. For example, if we have five items 4, 7, 9, 12, 15, the median is 9 since there are two items above that value and two items below it. If we have an even number of items, the median is calculated as halfway between the central two items. For example if we have six items, i.e., 4, 7, 9, 12, 15, 20, the median would be calculated:

$$\frac{9 + 12}{2} = 10.5.$$

microeconomics- Economics relating to the study of parts of an economy and how they function rather than to the total economy and its aggregate performance. Individual firms and consumers are analyzed concerning wages, prices, inputs and outputs, supply and demand, among other things. See: Macroeconomics.

mode- The observation which occurs most frequently in a set of observations. It is a measure of central tendency in a frequency distribution. Often used to average weekly sales and purchases. For example, in the distribution: 2, 3, 5, 5, 8, 12, the mode is 5.

model- A representation of the relationships that define a system or situation under study. Its purpose is to predict what will happen when a system becomes operational in terms of performance and output. A model, with its analytical discipline features, may be a set of mathematical equations, a computer program, or any other type of representation, ranging from verbal statements to physical objects.

deterministic model- A model in which the variables take on only definite values, that is, a model that does not permit any risk as to the magnitude of the variables. For example, a set of simultaneous equations for which there is a unique solution.

probabilistic model- A model in which each variable may take on more than one value. Such models are sometimes called stochastic and values are assigned according to probability distributions.

monetary policy- A principle or guideline relative to government actions concerning the availability of money and its impact on employment, prices, and economic growth. Relates to the Federal government economic stabilization policies, primarily executed by the Federal Reserve System, designed to achieve economic goals such as high employment, stable growth and prices, and balance of payments equilibrium, through influence on the money supply, interest rates, and credit availability.

Monte Carlo methods- A catch-all label referring to methods of simulated sampling. When taking a physical sample is either impossible or too expensive, simulated sampling may be employed by replacing the actual universe of items with a universe described by some assumed probability distribution and then sampling from this theoretical population by means of a random number table.

normal (Gaussian) distribution- The most used distribution in statistics because it represents a wide variety of actual distributions in nature and because it simplifies a number of statistical calculations. It is a continous distribution in the form of a bell-shape curve. Its important feature is that it is completely determined by its mean and standard deviation.

objectives- Statements of what we are trying to accomplish and why, set forth, if possible, in measurable terms. In analysis, objectives are stated in a manner which does not preclude alternative approaches.

obligations- Commitments made by agencies, during a given period, to pay out money for goods, services or other purposes during the same or a future period. Obligations incurred may not be larger than the budget authority apportioned for the period.

operations research (OR)- Systematic effort to provide decisions concerning systems. OR may present a solution to a problem or present the pros and cons of alternatives. Taking an objective as given, OR focuses

on ways to optimize realization of that objective in terms of some criterion such as cost, time, distance, speed, etc. A distinctive feature of OR is its application of one or a combination of the scientific disciplines such as mathematics, biology, chemistry, physics, statistics, etc., in addition to subjective methods such as common sense and judgments based on experience. OR might, for example be used by a manufacturer seeking the most efficient method of producing large quantities of electronics equipment on government contract.

optimization- A determination of the best mix of inputs to achieve an objective. An optimum may be derived by differentiating an appropriate function (mathematical equation expressing relationship of input to output) with respect to each variable, setting the resulting equations equal to zero and solving them simultaneously. For example, the optimum frequency for scheduling vehicle maintenance for a number of vehicles is the frequency which equates the costs of maintenance with the consequences of deferred maintenance. If the frequency is too high, you are overspending on maintenance; if too low, the cost of breakdowns will be excessive.

outcomes- The results of operations.

outlays- Checks issued, interest accrued on the public debt, and/or other payments made, net of refunds and reimbursements.

outputs- Program results such as goods produced and services performed expressed in quantities relatable to specific inputs, organizational missions and functions. Outputs provide a basis for evaluating the productivity and efficiency of an organization or activity. See: Benefits; Effectiveness.

output measures- Quantitative, qualitative, or comparative measures of output such as: 1) gallons of water purified, 2) the oxygen content of water purified, and 3) gallons of water purified per housing unit.

parameter- A numerical characteristic relating to or describing a population, which can be estimated by sampling. Differs from a statistic which is derived from a sample. For example, μ is the parameter for the mean of population while x is the statistic for the sample, an estimate of μ. Parameters are frequently denoted by Greek letters to distinguish them from corresponding sample values.

Pareto optimum- A concept in welfare economics that sets the conditions that maximize the economic wealth of given society. The Pareto optimum is said to have been achieved when it is impossible to make one person better off without making another (or others) worse off.

payback period- The length of time over which an investment outlay will be recovered. Also referred to as payoff period or cash recovery period.

pecuniary spillover- A spillover which is monetary rather than physical in nature and which causes a change in the monetary valuation of a physical input or output, but does not change the relationship between physical inputs and physical outputs. For example, an acceleration of a man-to-Mars program timetable might cause a short run shortage of professionals and technicians thus increasing the costs of similar services to other industries but not necessarily changing the physical productivity of these inputs to the other industries.

point estimate- An estimate which is expressed in terms of a single numerical value rather than a range of values.

policy- A governing principle, pertaining to goals or methods. A decision on an issue not resolved on the basis of facts and logic only.

population- The total number of elements within an area of interest. For example, the total number of inhabitants in a country or the total number of vouchers for a program. Also referred to as universe. See: Sample.

precision- Exactness of measurement. For example, a yardstick marked off in units 16 to the inch is more precise than one marked off in eigths. Also, in pointing off a decimal, 5.763 is more precise than 5.8. In statistical sampling, an estimated mean of 10 feet having a standard deviation (SD) of 1 foot has greater precision than an estimate of 10 feet having an SD of 2 feet, but has the same precision as another estimate of 20 feet which has an SD of 2 feet. In statistical inference, the measure of precision is the size of the interval within which the value being estimated is predicted to be found with a specified degree of assurance, based upon the results obtained from a sample. There is a tradeoff between the degree of precision of an estimate and the degree of assurance with which it may be made. If a less precise estimate, that is, one with a wider interval, is tolerable, the degree of assurance or confidence level can be increased.

present value- The present worth of past or future benefits and costs determined by applying discount procedures to make alternative programs and actions comparable regardless of time differences in the money flows. See: Discounting, Discount factor, Discount rate.

present value benefit- Calculation of each year's expected monetary benefit multiplied by its discount factor and then summed over all years of the planning period.

present value cost- Calculation of each year's expected cost multiplied by its discount factor and then summed over all years of the planning period.

price- The amount for which a good or service is bought or sold.

price, equilibrium- The amount of money represented by the intersection of the supply curve and the demand curve.

priority- Ranking of decisions, projects, programs according to urgency with which they are deemed needed. Often involves ranking related to spending budget.

probability- Numeric expression of the likelihood or chance of occurrence of a given event or outcome. Usually expressed as a percentage or proportion computed by dividing the total number of items, values, events, or outcomes of a specific type in a given group or universe by the total of all possible types of items, values, events, outcomes in the same group or universe. For example, in a universe of 1000 vouchers containing 250 receiving vouchers, 700 shipping vouchers, and 50 inventory adjustment vouchers, the probability that a voucher selected at random is an inventory adjustment voucher is .05(50 divided by 1000).

probability distribution- The listings of possible values of a variable (Y) and their associated probabilities. When summed over all possible values of Y, these probabilities will equal 1.00. In the example in the preceding definition of probability, the probability distribution is:

Shipping vouchers	.70
Receiving vouchers	.25
Inventory adjustment vouchers	.05
	1.00

Some commonly used probability distributions are binomial, hypergeometric and Poisson, which are discrete distributions, and the normal or Gaussian and the F distribution which are continuous distributions. The continuous probability distribution is one in which an infinite number of values of a variable can occur. For example, the amount of time it takes to fix a flat tire is a continuous variable because time can be subdivided into an infinite number of values. A discrete distribution, on the other hand, is one in which only isolated values can occur. For example, the number of tires on a car which have a flat is discrete being either 0, 1, 2, 3, or 4.

program analysis- The generation of options respecting goals and objectives as well as strategies, procedures and resources by comparing alternatives for proposed and ongoing programs. Embraces the processes involved in program planning, program evaluation, economic analysis, systems analysis, and operations research.

program evaluation- Appraising the efficiency and effectiveness of ongoing or completed programs. Aims at a program improvement through comparisons of existing programs with alternative programs and techniques. Uses actual performance data to gauge progress towards program goals.

programming- Programming is the process of deciding on specific courses of action to be followed in carrying out planning decisions on objectives. It also involves decisions in terms of total costs to be incurred over a period of years as to personnel, material, and financial resources to be applied in carrying out programs.

quantification- The measurement (not valuation) of the inputs, outputs, or benefits of a program. Consists of listing of the magnitudes of all important results, favorable and unfavorable, to which a program will give rise.

queuing techniques- techniques used when a problem involves providing a supply of goods and services in order to satisfy randomly arriving demands for these goods and services. More specifically, the techniques associated with operations research which determine the amount of delay that will occur when operations (such as supplying goods or services) have to be provided in sequences for objects (such as customers) arriving randomly. Queuing theory may be applied to any operation in which objects arrive at a service facility of limited capacity.

random variable- A variable whose magnitude is determined by chance.

range- The difference between the smallest and largest quantity in a statistical series arrayed according to size. The simplest measure of the dispersion in a set of numbers. For example, the range for series of the four numbers 10, 13, 40, 53, is 53 - 10 = 43. Also the difference between the largest possible value of a variable (random or not) and its smallest possible value.

receipts, accrued- Revenues earned (less refunds paid or payable) and other receipts due in during the period regardless of dates actually received.

regression analysis- Analysis undertaken to determine the extent to which a change in the value of one variable, the independent variable, tends to be accompanied by a change in the value of another variable (the dependent variable). Where only one independent variable is involved in the analysis, the technique is known as simple regression analysis; where two or more independent variables are involved, the technique is called multiple regression analysis. If the relationship between two variables can be depicted graphically by a straight line, it can be defined mathematically by an equation of the form:

$$y = a + bx$$

where y is the dependent variable and x is the independent variable. Multiple regression analysis can similarly be defined by an equation of the form:

$$y = a + bx_1 + cx_2 + dx_3 \ldots zx_n$$

but in this case graphical representation would have to be multidimensional.

If the change in the dependent variable associated with a change in the independent variable does not occur at a constant rate, the regression line takes the form of a curved line and the analysis is referred to as curvilinear regression analysis. Regression lines are drawn or defined in such a way that the sum of the squared deviations (the squares of the vertical distance of each point from the line) is smaller than would be the sum of the squared deviations from any other line which could be drawn. The relationships identified by means of regression analysis are associative only; causative inferences must be added subjectively by the analyst or obtained by other means.

resources- Assets available and anticipated for operations. Includes items to be converted into cash and intangibles such as bonds authorized but unissued. Includes people, equipment, facilities and other things used to plan, implement and evaluate public programs whether or not paid for directly by public funds.

revenue- Amounts realized from sales of outputs or assets, from collections of taxes and duties, and from contributions and other receipts incidental to operation.

risk- "Measurable uncertainty" per the economist Frank Knight. In decision theory, the distinction is made that risk is measurable while uncertainty is not. In situations of risk, the probabilities associated with potential outcomes are known or can be estimated. The term may be associated with situations of repeated events, each individually unpredictable but with the average outcome highly predictable.

sample- A subset of the population. Elements selected intentionally as a microcosm representative of the population or universe being studied.

sample, random- A sample selected on basis of probability that each element of the population has an equal chance of being selected. Equal chance of selection for each element in the population may be insured by the sample design. One procedure utilizes a table of random numbers to indicate elements to be included in the sample.

sample, simple random- A random sample of units selected with equal probability and without replacement from a finite population.

sample size- The number of cases (population elements) selected for the sample. Although a number of factors influence the determination of sample size, major factors are the variability of the principal characteristic (in its population) to be estimated, and the confidence level and confidence interval the decision-maker can tolerate. The size of the population or universe is a minor influence. There are many formulae and variations thereto for computing the sample size for any problem.

sample, stratified- A sample consisting of random samples from subgroups, or strata, of the population. The population is stratified for the purpose of sorting out homogeneous groups of elements. This in turn reduces overall sampling error by decreasing the variance between the elements in their respective strata. Stratified proportional samples are often designed to minimize variance by stratifying the population according to some available size criterion.

satisficing- A term, advanced by Herbert Simon, which views decision-making as a process of reaching satisfactory positions (satisfying and sufficing) rather than optimal positions, where the standard of satisfactory is given bv complex psychological and sociological considerations.

savings- Reductions in costs.

scalar- A quantity having magnitude but no direction as contrasted with a vector which has both. It is simply a constant or a number. An example would be body temperature.

scenario- A narrative description of the problem or operation under analysis including the sequence of events, environment, scope, purpose and timing of actions. For example, a scenario might be useful for describing the operations involved in operating a branch office to receive and process applications for food stamps. It may or may not include objectives, standards, and guidelines. It should be dated to insure that the need for updating will be recognized.

sensitivity analysis- A procedure employed as a result of uncertainty as to the actual value of a parameter or parameters included in an analysis. The procedure is to vary the value of the parameter or parameters in question and examine the extent to which these changes affect the results of the analysis. For example, if an analysis indicates that program A is preferable to program B, sensitivity analysis might be performed by increasing a factor such as size of the group to which the programs are directed and then examining the results of the analysis under this change. See also: contingency analysis.

shadow pricing- Imputing the prices of inputs, outputs, or benefits. Inventing prices for goods or services for which there is no established market. For example, the average hourly value to a person attending a proposed new outdoor recreation facility might be assumed to be more or less than what he now spends to participate in a similar activity.

simulation- An abstraction or simplification of a real world situation. In its broadest sense any model is a simulation, since it is designed to represent the most important features of some existential condition(s). Generally, however, the term simulation is used to refer to a model which is being used to determine results under each of many specific sets of circumstances rather than one which is being used to determine an optimal solution to a problem. Simulations may take the form of either deterministic models or probabilistic models.

Man-machine simulation is simulation in which both computing machines and human decision-makers interact in simulating a process or system. Most of these simulations can be legitimately categorized under the heading of "gaming". Reference to those simulations that are carried out solely by machines is called pure-machine simulation. This is in contrast to man-machine or all-man simulation in which human decision-makers serve as part of the model.

spillover- An economy or diseconomy for which no compensation is given (by the beneficiary) or received (by the loser). Spillover is sometimes synonymous with externality and with external economy or external diseconomy.

standard deviation- A measure of dispersion (deviation of each observation from the mean) or degree of spread in a series of numbers. The square root of the average of the squared deviations of the individual values, Y, from their mean, μ. Denoted algebraically:

$$\sigma = \sqrt{\frac{\sum(Y_i - \mu)^2}{N}}$$

For example, the two sets of values 3, 4, 5, 6, 7 and 1, 4, 3, 15, 2 have the same mean, 5, but standard deviations of 1.4 and 5.1 respectively. This difference reflects the fact that the values in the second set are more widely dispersed around their mean than are the values in the first set.

statistic- A measure, quantity or value, such as an average or proportion, which is calculated from a sample to estimate the corresponding parameter of the population.

sunk costs- Costs which have already been incurred and will not be increased or decreased by any decision made either now or in the future. Therefore, such costs have no relevance to decisions regarding future action. For example, in making a decision as to whether a new plant should be constructed, the construction cost of the existing plant is a sunk cost.

supply- The schedule of quantities of goods and services that producers are willing and able to offer at given prices. Also the function, or process of requisitioning (or ordering), storing, and issuing the materials and supplies required for operations.

systems analysis- The process of investigating, in its broadest sense, the total context within which a problem exists or within which a decision must be made by examining the interacting pieces of a system and applying

the methods of science to find out what makes it work. Develops information for the decision-maker that will help select the preferred way of achieving the objective. Has been called the application of enlightened judgment aided by modern analytical methods for decisions concerning systems of broad scope.

technological life- Estimated number of years before the existing or proposed equipment or facilities become obsolete due to technological changes.

technological spillover- A spillover which affects the relationship between physical outputs and physical inputs of some external entity which does not pay or receive payment for the spillover. For example, chemical fumes from an industrial plant which reduce (or increase) the yield of crop land.

time series- Observations on a variable at consecutive points in time or during consecutive intervals of time. For example, annual consumer expenditures for each year during the years 1950-80.

trend- The change in a series of data over a period of years, remaining after the data have been adjusted to remove seasonal and cyclical fluctuations. For example, the annual increase in output over a period of several years excluding fluctuations due to the business cycle.

uncertainty- State of knowledge about outcomes in a decision which is such that it is not possible to assign probabilities in advance. Ignorance about the order of things. Some techniques for coping with this problem are a fortiori analysis, contingency analysis and sensitivity analysis.

utility- The real or fancied ability of a good or service to satisfy a human want. Usually synonymous with satisfaction, pleasure, or benefit.

valuation- The process of reducing to a common base (dollars, for example) measurements that are made on different scales. It involves establishing trade-offs, or comparison weights, between multiple objectives. The weights represent policy decisions. The valuation of benefits is not to be confused with the quantitative estimates of benefits. For example, it is one thing to estimate the number of lives saved by a program, but it is another matter to place dollar value on lives saved.

value- The desirability, utility, or importance of a thing or an idea. Usually worth in money. Frequently represented by price. The value of a good or service is what a consumer is willing and able to give up to have it. To have value, a thing must be desired and some degree of scarcity involved. The value of wheat, for example, is expressed in dollars per bushel. Also, the quantity in terms of which a variable may be expressed. The variable x, for example, may represent bushels of wheat produced in the various States and these values may range from 3 million bushels, in one State, to 10 million in another.

variable- A characteristic having magnitudes expressible numerically which may vary from one case or observation to another. Since a variable can take on different values, it must be represented by a symbol instead of a specific number. For example, "x" may represent the height of humans; given a specific human, the variable x would take on a specific numeric value.

variable, dependent- A variable whose value is determined by other variables (or constants) in the structure of an equation or mathematical expression.

variable, predetermined- Variable determined before and independent of any decisions taken by the researcher.

variance- A measure of the dispersion of population elements about the mean of the population. It is calculated by:

$$\sigma^2 = \frac{\sum (Y_i - \mu)^2}{N}$$

where N = size of population
μ = mean of population
i = ranges from 1 to N

For example:

Population A

Y	$Y-\mu$	$(Y-\mu)^2$
4	-1	1
5	0	0
6	1	1
15		2

μ = Y/N = 5
σ^2 = 2/3 = .67

Population B

Y	$Y-\mu$	$(Y-\mu)^2$
1	-4	16
5	0	0
9	4	16
15		32

μ = Y/N = 5
σ^2 = 32/3 = 10.67

The mean of both these populations is 5. However, population A has a much smaller variance than population B, indicating less dispersion of the values of Y about the mean.

vector- A quantity having magnitude and direction. It may be considered to be a matrix of either several columns and one row or several rows and one column. A vector may be contrasted with a scalar which has only magnitude and no direction. It is described by a set of numbers in much the same way as a point on a map is described by its coordinates.

welfare economics- The study of the economic well-being of all persons as consumers and as producers, and possible ways in which that well-being may be improved. It is also known as normative price theory.

zero base budget- A procedure for justifying a budget assuming the base to be zero. Requires a justification for the base of the program each year, rather than the incremental amounts by which the budget request exceeds previous year.

zero-sum game- A game in which the sum of the gains (X wins two points) exactly equals the sum of the losses (Y loses two points).

APPENDIX H

BIBLIOGRAPHY

The following references may be useful to the reader looking for background information to expand his/her knowledge of cost/benefit analysis or for the performance of a particular analysis or review. (Nevertheless, where procedures described differ from Navy practice, the Navy analyst should take care to follow guidance listed in Appendix C.)

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APPENDIX I

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